THE MAY SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

THE SCIENCE PRESS

LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

NEW BOOKS OF SCIENTIFIC INTEREST

Mathematics for the Million. LANCELOT HOGBEN. Illustrated. xii + 647 pp. $3.75. Norton.

An attempt to explain, simplify and clarify mathematics for the layman. The author discusses mathematics in prehistory, number language, geometry, arithmetic, trigonometry, algebra, spherical triangles, graphs, logarithms, calculus, and the arithmetic of human welfare.

Marconi the Man and His Wireless. ORRIN E. DUNLAP. Illustrated. xxi + 360 pp. $3.50. Macmillan.

A biography of Guglielmo Marconi introduced with a brief preface by the inventor. The author has endeavored to present impartially the significant facts in the history of wireless and to interpret Marconi's rôle in its development as well as to tell the story of his life.

Essential Principles of Organic Chemistry. CHARLES S. GIBSON. viii + 548 pp. $5.00. Cambridge.

A study of chemistry of carbon compounds for those who will work in the field of biochemistry and physiology as well as for future organic chemists. The author has had special regard for the importance of laboratory work and the practical side of the subject is specially emphasized.

The World of Science. F. SHERWOOD TAYLOR. Illustrated. xvi + 1064 pp. $3.75. Reynal and Hitchcock.

An attempt to answer in simple terms the questions which laymen ask in the field of the natural and exact sciences. This popular encyclopedia is divided into six parts: The States of Matter, Power, Waves, Chemistry, The Earth and Heaven, and Life.

Culture Methods for Invertebrate Animals. Edited by P. S. GALTSOFF, F. E. LUTZ, P. S. WELCH, J. G. NEEDHAM. xxxii + 590 pp. $4.00. Comstock.

A compendium prepared by over 150 zoologists under the direction of a committee of the American Association for the Advancement of Science. It gives methods for the management of cultures of a wide range of invertebrate animals.

Vitamins in Theory and Practice. LESLIE J. HARRIS. Illustrated. ix + 242 pp. $3.00. Cambridge. (Macmillan.)

Dr. Harris presents, for the general reader, a narrative of the progress and history of vitamin discovery and research. He explains how vitamins were discovered, how they work in the human system and the various types of illness caused by vitamin deficiency.

Elementary Chemistry. D. G. HILL, J. H. SAYLOR, W. C. VOSBURGH and R. N. WILSON. vi + 473 pp. $2.80. Holt.

A general textbook of chemistry including descriptive and theoretical material for first year college students. One of the objects of the book is to present modern electrolyte theory in simple terms and make use of the modern theory of atomic structure.

Biological Time. P. LECOMTE DU NOÜY. xiv + 180 pp. $2.00. Macmillan.

In this book, methods are described for the measurement of physiological time, and for the study of its characteristics. Physiological time has been estimated in two different ways: by the rate of wound healing, and by chemical changes taking place in blood serum.

Weather Rambles. W. J. HUMPHREYS. Illustrated. 265 pp. $2.50. Williams and Wilkins.

A book of the weather in which Dr. Humphreys tells odd and interesting things about the winds, clouds, air-masses, dews, frosts, rains, snows, prairie twisters. He also passes on many curious items of meteorologic lore.

In Quest of Gorillas. W. K. GREGORY and H. C. RAVEN. Illustrated. xvi + 241 pp. $3.50. Darwin.

A narrative of an American Museum of Natural History-Columbia University expedition into the heart of Africa in search of gorillas, relating scientific details, descriptions of nature, people and animals. It is the March selection of the Scientific Book Club.

Adventures in Bird Protection. THOMAS GILBERT PEARSON. Illustrated. xiv + 459 pp. $3.50. Appleton-Century.

The autobiography of the president emeritus of the National Association of Audubon Societies who has devoted his life to the study and preservation of birds. The story of his life automatically records the background and work of the association, which was founded in 1905.

Birds Around the Year. LORINE L. BUTLER. Illustrated. xi + 242 pp. $2.00. Appleton.

This introduction to bird lore is organized on a seasonal basis, tracing the movements and activities of birds through spring, summer, autumn and winter. The author describes types of bird songs, mating and nesting habits, care and training of young and migration of typical species.

The Book of Animal Life. T. STOWELL and T. W. BURGESS. Illustrated. xii + 315 pp. $2.50. Little, Brown.

A description of the ways in which animals meet the problem of living. The author tells how the common wild animals make their homes, work, play, perpetuate their kind, care for and train their children, etc., in order that young people may have a better appreciation of animal life.

Our Children in a Changing World. E. WEXBERG and H. E. FRITSCH. xii + 232 pp. $2.00. Macmillan.

An outline of practical guidance written in three parts: General Problems, Special Problems, and Education and Corrective Measures. The book deals with the development of personality, the factors of environment, types of children, bad habits and nervous symptoms.

Vol. XLIV, No. 5 May, 1937 Whole No. 260

The Scientific Monthly

An Illustrated Magazine Devoted to the Diffusion of Science

J. McKEEN CATTELL, Editor

WARE CATTELL, Associate Editor

Published by THE SCIENCE PRESS

LANCASTER, PA.—NEW YORK, N. Y., Grand Central Terminal—GARRISON, N. Y.

Single Number, 50 cents Yearly Subscription, $5.00

Entered as second-class matter at the post office at Lancaster, Pa., July 18, 1923, under the Act of March 3, 1879

THE SCIENTIFIC MONTHLY

MAY, 1937

AN ASTRONOMER LOOKS AT THE MODERN EPOCH

By Dr. JOHN Q. STEWART
PRINCETON UNIVERSITY OBSERVATORY

(1) Introduction

In observatories and universities a livelihood is provided for astronomers who look at and think about planets, stars and galaxies. What business have astronomers to look at, to criticize, the modern epoch? Astronomy had much to do with its inception. Ways of living and of thinking based on the successes of natural science *are* modernity. That is all.

The modern period differs from its predecessor medieval principally in knowledge of science and in the influences of this knowledge on material and cultural environment. The concrete control which technology exercises, on the whole beneficently, over material surroundings is evidenced so emphatically that it need not be stressed in this talk. The equally significant abstract control which the ways of thought of scientists exercise over all men's ways of thought is little recognized. This second influence of growth and spread of scientific knowledge I shall attempt to sketch with astronomical detachment.

Historians set up other, less important, distinctions between the medieval and the modern, but in a brief discussion arbitrariness can not be avoided. The first modern science (except for elementary branches of mathematics) was seventeenth-century mechanics, which was based by Sir Isaac Newton on the kinematics of Galileo and the astronomy of Kepler. Newton lived from 1642 to 1727. His method of thought still serves as a model for most scientific thinking, although his particular results have been elaborated in detail or superseded in fundamentals. Among all innovators who initiated modernity, Newton's is the outstanding and synthetic name.

The majestic sequence of discoveries of fact and constructions of concept from Ptolemy through Newton has been described often enough. It has been given, you recall, poetic form by Alfred Noyes, in his "Torchbearers." On some later occasion I hope to give it consideration as a case in a novel symbolic logic. Logic and poetry need not be far apart. First, let us refresh our memories with a rapid outline of the work of the early astronomical discoverers.

(2) From Ptolemy through Newton

Claudius Ptolemaeus, in the second century A.D. near Alexandria, summed ancient astronomical lore in a text which, centuries later, was called "The Greatest" by admiring Arabs. Although he understated its size, the earth for Ptolemy was a sphere, and it was unmoving at the center of the universe of planets and stars. He endorsed also the hypothesis that the motions of all celes-

tial bodies be accounted for by combinations of elementary motions which were always uniform and circular, and he showed how observations of the varying angles at which we see celestial objects could thus be explained with accuracy, albeit with some intricacy. Little was added in fourteen hundred years. In 1543 Copernicus published from Poland his revision of the Ptolemaic theory, which made the sun central, although still keeping to representation by uniform circular motions. The idea that the sun might be central, rather than the earth, had been suggested about 250 B.C. by Aristarchus, but Ptolemy's opinion had negatived it throughout the medieval period, during which scholarly interest was concentrated on reasoning by deduction from assumed first principles rather than on reasoning from exhaustive observations made with modern alleged openness of mind. Central tenets of the medieval schools were summed in the supreme writings of Thomas Aquinas, who died, aged about 47, in 1274; he taught that philosophy and theology, reason and revelation, were compatible. For lesser minds, authority falsely borrowed from the theology began to gild with unjustified permanence the principles of long-accepted science.

Tycho Brahe, the great Danish astronomical observer, was born in 1546, the year when democratic Martin Luther died. Tycho redetermined, with precision which had not been reached before, positions of stars and planets. He was exiled in old age from his splendid Baltic island-observatory, and John Kepler in Austria became the fortunate and adequate heir to his manuscripts. Tycho was supreme as an observer, and not especially endowed with genius for speculation. Kepler was not in the least an observer. His passion for seeking harmony in all things resulted in sublimation of Tycho's laborious data into Kepler's three brief rules of planetary motion. His first and second displaced the antique uniform circularity by varying but predictable motion in ellipses; his third arithmetically related the periodic times to the distances of the planets and so introduced into the arbitrary-looking geometrical formalism of Ptolemy and Copernicus a numerical Pythagorean fury, a fresh magical unity. Quantitative relations of similar character in physical science are so familiar now that it requires imagination to sympathize with Kepler's unspoiled delight at this premier discovery. It remained for Newton to resolve Kepler's three laws in "scientific" terms.

Galileo was physicist before he became astronomer; the year, 1564 (when Michelangelo died), was the year of his birth (and Shakespeare's). The Tuscan physicist in 1610 first among men turned a telescope against the stars, and his was the greatest artistry among contemporary astronomers. Because of his lively endorsement of the unorthodox Copernican theory and because of his vigorous exercise of experimental methods in physical science at a time when leaders in affairs academic were sympathetic only with deductive argument *a priori*, Galileo late in life came into conflict with the ecclesiastical powers. He was reprimanded, he was imprisoned mildly, he was deprived of opportunities for teaching. The great school of physical and mathematical research which he might have founded in Italy—where was no lack then of students of ability—with all the technological and economic advantages to his country which would have flowed from such a school, became merely another one of history's might-have-beens. As physicist, Galileo studied the motions of falling bodies; he displaced the old Aristotelian animistic "elements" (fire, air, earth, water) by the modern emphasis on distances and times, and he established arithmetical

rules for predicting uniformly accelerated motions.

In the year when Galileo died, blind and harassed, 1642, Newton was born. Except that Sir Isaac Newton, when elderly, wrote of theology—and, be it noted, theology, although severely attenuated, is still with us—there was nothing medieval in his mind. His English environment was sufficiently modern, in contrast to Galileo's, for him to be nourished in it with acclaim instead of persecution. His mighty dynamics combined in new first principles Kepler's empirical astronomy with Galileo's empirical physics, through enunciation of the three laws of motion and the law of universal gravitation. To Galileo's distance and time, Newton added his own new abstraction, mass, as the third necessary and sufficient "dimension" of mechanics. His compact theory is set forth within a few pages in elementary text-books. It has met every numerical test in the *a priori* elucidation of every observed celestial and terrestrial motion, except when velocities are very great or masses exceedingly minute.

The concern of Kepler, Galileo and Newton with quantitative description of observed facts has been ever since the growing concern, not only of physics but of all scholarship.

(3) The Elements of Modernity: Distance, Time, Mass, Number, Fact, Machine

The slowly developing germ of modernity reached full intensity in Newton; it needed only to spread. It has spread from English Cambridge to both poles; to Pacific depths, to the treacherous air over Everest and to the rarity of the stratosphere; and to thought about life and society and art; shaping mysteries of earth and man to the sharp necessities of ***distance, time, mass, number, fact, machine.***

These six terrific idols of the modern mythology may stand on feet of clay; but let us examine first their firm superstructures, their exciting exteriors of porphyry and gold.

Distance: Some of the ancients knew pretty correctly the diameter of the earth, even the distance to the moon, but all much underestimated that of the sun. It was an improved measure of the earth that enabled Newton to verify his hypothesis that the gravitation which curves the moon's orbit is the gravity which makes ripe apples fall. Surveyors chain the fundamental arcs of earth by methods which every surveyor understands; from the baseline of the earth's diameter meticulous astronomers triangulate the distance of the sun. With that radius, 92,900,000 miles, the astronomical unit, now as base, they trigonometrize the nearest stars, hundreds of thousands of those units away. Indirect methods utilizing various properties of stars are called to aid, and the diameter of our stellar system, the wheeling galaxy, intricately is estimated as tens of thousands of times greater yet.

The telescopes plunge deep to other galaxies, and the present maximum observable distance stands in the same ratio to the astronomical unit as that unit, 92,900,000 miles, bears to one tenth of an inch. On the other hand, physicists, studying atomic and electronic phenomena, deal definitively with distances scores of billions smaller than an inch.

Superficial consideration might suggest that what might be called the distance per capita, the individual citizen's share in space, has increased proportionately with civilization's increasing command of space. This is certainly true as regards modern ease of travel, between all latitudes and longitudes on the circled planet. The modern traveler, however, is likely really to experience little of the varied course between his

departures and destinations: rivers, cities, mountains, tides and storms—except the severest—whirl nameless and unnoted past his rapid easy-chair. Impoverished Indians who fished and swam and drank Manhattan's brooks, and watched the stars rise and set in transparent skies, were heirs to vastness denied for renters in the city blocks, who pay scores of dollars per year per cubic yard for airless space to call their own.

Time: The precession of the equinoxes was discovered and underestimated in the second century B.C. by Ptolemy's learned forerunner, Hipparchus. This "great year" of the top-like wavering of the earth's axis occupies about twenty-six thousand years; it was the longest interval of time the ancients dealt with; but of course no one knew then whether even one revolution had been completed. Students of Biblical chronology are said to have arrived at more than two hundred different results for the date of creation, ranging from 7000 to 3500 B.C., the date 4004 B.C. being finally authorized by seventeenth-century Archbishop Usher. Studies of radioactive transformations in minerals indicate now that the earth's crust has been undisturbed by major cataclysm for almost two billion years. This is speculatively taken as the age of the solar system and even of the universe—the so-called "short" time scale in stellar astronomy. The "long" scale is uncertainly greater by a factor of a hundred.

The life of a man comprises about as many seconds as there are years in the undisturbed age of the earth's crust. At time's small end it is hard to fix the temporary present-day limit; physicists speak of radiation-vibrations as short as one trillionth of a second, but what is it that vibrates?

Throughout history the positions of the sun and moon among the stars and their risings and settings have been utilized to regulate days and calendars. As society became more organized, synchronisms and chronologies took more definiteness, not at first in dead numerical terms. We may think of the trumpets of encamped legions of the Caesars as sounding reveille, mess-calls and taps. A few centuries later, monastery life in Europe gently marched to matins, lauds, prime, terce, sext, none, vespers and compline. Galileo's pendulum made accurate clocks a commonplace, and thorough-going time-mindedness began in the western world. To-day factory whistles or railway schedules call workers from and return them to their families; and the more important a man is in affairs the more likely is his alert week to be partitioned off by a squad of critical secretaries in measured quarter-hours; while every shanty in the shortwave radius may possess a broadcast receiving set on which, precisely on the second at 9 P.M., the fragment of a symphony is chopped off in order to introduce the Hottentot Roysterers and their sponsor's importunities.

Mass: Newton's mass is quantity of matter; we have evidence now that it is convertible, and reversibly so, to energy. The mass of the earth was first estimated, with fair accuracy, in 1774, by Maskelyne; it is, in tons, 6,000 billion billion. Extrapolation of the gravitational attraction between two small known laboratory masses at a measured distance gives the best method of determining it. Study by the methods of celestial mechanics of the earth's orbital motion around the sun yields the mass of that attracting center, and this comes out 332,000 times the earth's. The masses of many double stars, which rotate about each other, similarly have been computed; stars roughly duplicate the sun in mass. The mass of the galaxy can be guessed at, and is billions of times the sun's; our galaxy is one of scores of millions within range of existing telescopes.

As a man's mass is to the earth's, so is the earth's to that of the seeable mate-

rial universe—and this infinitesimal ratio is also about equal to the ratio of the mass of the largest organic molecules to the mass of a man; but the mass of an electron or positron is a hundred million times smaller still, and low-frequency photons run smaller again by tens of thousands or millions.

There are ninety-two chemical elements—that many drastically different theoretical primitives of matter—themselves electrically constituted; the myriad combinations of these elements under varied temperatures and pressures are chemistry. All but perhaps two of the ninety-two actually have been found in the earth's accessible skin. Sixty-one have made their presence on the sun known in sunlight, and dozens of these have been identified as well among the farthest stars; and a few in the evanescent clouds which float between the stars. Perhaps additional elements more complex can be formed above the ninety-two. Electronic bombardment at voltages in the millions transforms one element into another of higher or lower atomic weight. An up-to-the-minute "nuclear physics" deals with this bewildering alchemy, making with its isotopic complexities a new chemistry underlying chemistry. Inorganic chemistry merges into mineralogy in the study of crystal structure; and the "organic" chemistry of carbon compounds rises to complexities which seem to vie with those of living bodies; and physiological secretions, in turn, play a large and as yet incompletely appreciated part in conditioning the psychological attributes of life.

Compare the mass and the mass per capita of a savage's equipment with that of a subway-riding New Yorker. For the one the strong arms of his squaw harvested the Indian corn; for the other flying freights and motor trucks converge on metalled roads with refrigerated produce from a dozen states. The trusty twang of the one's bow and arrows outmatched the fleetness of squirrels, rabbits and deer, except during famine winters; the other hopes in his precarious hunting to succeed through the strength and cunning of his factory-chimneys, showcases and filing-cabinets. For the one the easy poles and skins of a teepee, for the other, bricks, concrete and steel, and neon lights pile as high as the dark mountains which shield the old valleys of the Delaware, the Susquehanna and the Shenandoah.

Number: Number has been important during many epochs past—in the medieval, the dark ages, the ancient classical and the old cultures before; but it is only in the modern epoch that the importance of number has become so overshadowing and that the numbers themselves have become so large and well determined. In the first chapter of Genesis, 6 days were required to finish the heavens and the earth and all the host of them. The sixth chapter sets the dimensions of the ark in Noah's resettlement project as 300 by 50 by 30 cubits. Methuselah lived 969 years; is any larger number exactly given in the Bible? The poets of classical science, Aratus and Lucretius, do not make much play with numbers. In all-embracing thirteenth-century Dante, canto follows canto without inclusion of a number larger than 6 or 8. In *Hamlet* is such a passage as

Full thirty times hath Phoebus's cart gone round
Neptune's salt wash and Tellus's orbèd ground;
And thirty dozen moons, with borrowed sheen
About the world have times twelve thirties been—

Use of poetry as an index to the use of number is a little unfair. Modern poetry is equally innocent of arithmetic—but most of modern poetry may be as yet unwritten.

The evaluation of the ratio of the circumference to the diameter of a circle, "pi," has a longer history than any other numerical constant—except perhaps such astronomical ones as the ratio of the year

to the day, the year to the lunar month. Hipparchus could only discover precession by knowing the ratio of the year to the day as a number of four, almost five, significant places; we know it now to eight, to better than one part in 100 million, and the length of the lunar month to seven. Ptolemy used for "pi" 3.1415; by 500 A.D. the Hindus were using the familiar 3.1416. In 1527 (the invaluable 11th edition of the Encyclopedia Britannica states) two more significant places were established accurately; in 1579 four more; then Gregory, Mercator, Leibniz and Newton established formulae; and, by 1699, the first 72 digits in "pi" had been calculated. With the gluttony characteristic of modernity the computation during the nineteenth century was pushed to 707 places. Any accurate industrious clerk who cares to take the time can go farther. The proof that "pi" is transcendental, that no finite numerical expression for it ever will be found, is of theoretical importance to mathematicians.

Our Arabic numerals date from before the ninth century but were introduced in Europe much later. Following John Napier's invention of logarithms in 1614, the computation of another shadow-number—the mathematicians' "e," the base of the natural logarithms—began. The slogan "greatest good to greatest number" helped to spread political democracy. As celestial mechanics developed, the exact determination of astronomical constants proceeded apace. Recently, in another phase of astronomy, average times between eclipses for short period variable stars have been evaluated to eight precise digits. The first "universal constant" in physics uncovered was the speed of light, which was roughly found by an astronomer, Roemer, in 1675, from the eclipses of Jupiter's satellites; but not accepted until confirmed in 1726 by another astronomer, Bradley, from annual spurious displacements of stars. This tremendous velocity is now known at least to four figures. Followed, much later, determinations of the constant of gravitation, of the masses of atoms, of the charge on an electron and of Planck's constant. The numerical data of spectroscopy are very extensive; a few spectroscopic constants are reliable to eight places and a multitude to seven; careful investigators have given of their lives to make them so. The first pure *ratio* to appear in physics was that of the force of gravitational to the force of electrostatic attraction, which dates from Coulomb in 1785 and which even now is known only to three places. The second, that of the mass of the proton to the mass of the electron, appeared at the end of the last century, and is about 1847. The third involves Planck's curious "h," and is scarcely yet reliable to three significant figures. The most accurate values of chemical atomic weights are to five places. Bulky tables of physical and chemical constants give precise densities, specific heats, electrical conductivities, thermal coefficients and other quantitative characteristics beyond remembering of substances almost countless. Numbers swarm in all the handbooks of engineering. In manufacturing, automobile pistons are fitted with an accuracy of one five-thousandths of an inch. In biological laboratories, with patient statistics through years, genes in fruit-flies are enumerated; in clinics, physicians take blood-pressures and counts of blood-corpuscles.

In a day's newspaper we may scan the 50,000 accurate digits in stock-market reports which symbolize the shifting frenzy of devotees. On a single front page which carried—of all things medieval—an archbishop's rebuke to a king, you might have noted, in the headlines alone: "140,000 loyal Chinese soldiers" —"Germany needs 1,000,000 tons of wheat and 1,000,000 of rye"—"Compromise on 2 accords, text on page 14"—

"Twenty-five miles south of Vienna"—"Painting lost for 40 years"—"Cost of West Coast ship strike put at $311,750,000—"Volume LXXXVI, No. 28,814; second-class matter; December 14, 1936; price two cents in New York City; temperatures yesterday, max. 39, min. 27."

A tremendous tide of number rises around the perplexed modern man; every new number that swells this crest has relationships, tenuous or immediate, to every other number in the flood. Choice at Buenos Aires between 2 accords committing the Americas to joint neutralities conceivably may influence policies of a European nation whose grain reserves are gone, and echoes from those decisions will touch the controverted wharves of San Francisco and ripple to farther shores of Pacific. The number of such internumerical relationships is something like the number of combinations of n things taken m at a time; which, when n is only 1000—the headlines of a month—and m is 4, works out as 40 billion, and as n increases this beats against infinity. Such is the internal and infernal feedback of numbers which interrelate to produce new numbers in number exceeding comprehension.

The second law of thermodynamics avouches, what common sense confirms, that feedbacks such as this almost certainly lead any purely mechanical system away from stability and order. Whatever Newtonian shielding is set—whatever constraints are arranged that rely on physical force—the indefinite regress of numbers reflected in numbers will find some chink in arbitrary conditioning through which to enter and break treasured harmony.

The mathematician knows that confusion feeds naturally upon itself. Only the mystic can match harmony with stronger harmony.

Fact: Now to inspection, without reverence, of the fifth modern idol of the list I gave, the master of them all: his name is Fact. If all the "facts" presented in all the college courses in Princeton, or in any other university equally enlightened, were printed in normal type and strung end to end, the resultant ribbon, when roped around the football field, would form a series of impregnable walls hundreds of yards high. We start, if we like, with the course in "Ancient Architecture," tracing architecture's development from prehistoric beginnings through the historical periods of Egypt, Mesopotamia, Persia, Greece, the Hellenistic East and Rome, down to the fourth century A.D., when Christianity became the dominant factor in architectural evolution. This course gives the student a necessary acquaintance with significant buildings of the past as expressions of civilization, and grounds him also in terminology and in problems of architectural construction. Passing through catalogued A, B, C, "Elements of Economics" also is approached historically to explain the origin and growth of the present economic system. Value, price and distribution are treated; in continuation, economic security is taken as the central problem, and various proposals for increasing social control are examined. When *P* is reached in the Princeton curriculum, "Abnormal Psychology and Mental Testing" is presented, with the problems of insanity and feeblemindedness, including evaluation of hypnotism and the Freudian theory. Survivors who hardily keep on through *S* will find in the course about "Structures" an introduction (but only an introduction) to the theory and design of statically determinate beams and trusses; and principles of analytical and applied mechanics are illustrated in the calculation of stresses and in design of building frames, roof trusses and bridges; and minds not over-callow may learn how stresses are determined both by algebraic and by graphical methods, the latter including the Maxwell diagram, funicular

polygon and influence line. At long last, "Invertebrate Zoology" studies the classification, morphology, life-histories, embryology and habits of selected phyla of the invertebrates, with lectures, laboratory work and demonstrations. Results of a diagnostic examination which I inflicted two years ago on good-natured colleagues indicate that not one of the professors concerned with any one of these five courses would be able to pass the undergraduate examinations in any one of the other four.

Increasing plethora of newly described facts flows out in the publications and at the meetings of learned societies in all countries. The academic mills to-day are better equipped for production than for inspection: not every announcement which feeds from the busy assembly-lines is up to standards. Newspapers are devoting increased space to these varying findings, and it is going to be necessary to expect the journalists to be more critical than they have been.

When such an address as Sir Arthur Eddington's at the Harvard Tercentenary last September is front-paged, and a trusting laity is told that this stimulating author's latest mathematical calculations yield for the number of electrons and protons in the universe the figure 136 times 2 raised to the 256th power—surely the accurate reporter will not be indulging in news-column editorializing if he adds: "However, representative physicists from the brilliant audience whom I briefly questioned, emphasized the hypothetical nature of the calculation and stated that no such announcement could at present meet with firm acceptance among scientists, since the very limited relevant facts at our disposal are insufficient to guide the arbitrary mathematics."

Inadequacy of criticism is a predominant failing in modern academic organization. Criticism demands synthesis of knowledge; unless an expert has made himself expert in several widely diverse fields he remains a technician—and has his charm and usefulness; but he has to take most of his thought at second or third hand; and his judgment, even in his own field, is likely to remain immature. Varied expertness is impossible nowadays, most scholars will tell you with satisfaction, because there is so much scholarship that no one mind can compass much.

The driving synthetic responsibilities of civilization do not wait upon such recondite apologies, but are assumed by the well-intentioned ignorant—please number me with those—or by quacks who have been pushed forward to distract attention with their mummeries from a partisan selfishness. In such default of leadership, the native anarchy of events throughout the millenniums has had a way of destroying the very bones of civilizations which have lacked courage and brains to protect themselves from the consequences of their own excessive successes.

Machine: Before I altogether shed astronomical detachment, the sixth stern index which I have chosen for evaluating modernity remains to be considered: let us look at machines, and along with meter-sticks and clocks and balances, I mean to include mental machinery, routines of men's thought and action.

Gunpowder, the magnetic compass, the printing-press, ushered in primitive modernity; but even after Newton the rise of machinery remained for a century very slow. In the late eighteenth and early nineteenth centuries the steam-engine and the use of coal to yield a ubiquitous and reliable power accelerated mechanical development. Enlarging gains from industry and trade continually weakened anachronistic landed feudalism; public and private philanthropy and education flourished as material wealth increased. Growing speed in transportation linked distant areas more and more closely; before 1850 electricity was made to begin its not-even-yet-finished magics of com-

munication and control. Faraday and Joseph Henry were the Tycho-Keplers for electrodynamics, Maxwell became the Newton. Physics remained complacently Newtonian as the nineteenth century closed. Electricity and electromagnetic radiation had been incorporated into dynamics without disturbing underlying metaphysical presuppositions. Boltzmann had emphasized in thermodynamics and Gibbs in statistical mechanics the notion of probability, but its extra-Newtonian implications exercised few thinkers. Darwin, the engineer of Newtonian concepts in the world of life, had imposed his thought—of biological masses colliding and competing in time and space—on a not resistant late mid-century popular philosophy. Karl Marx during those same impersonal years was pushing Newtonianism one phase farther, into the theory of society, and his mechanistic economics was to wait through five decades before exploding across Russia's bicontinental stage. Even in the humanities the protean idea of a mechanistic evolution gave time new emphasis, and the historical approach became favorite.

The gas-engine appeared as the nineteen-hundreds ended; and amid growing speed and speedier amplification in the numbers of almost everything our own new century began. The airplane drove past the automobile; mass-manufacture rushed new devices to meet new wants, which were fostered by staccato advertising among an ever-expanding circle of purchasers—and what these purchasers used for money no economist understands. In psychology the behaviorists asserted that motions are the only activity by which minds are judged. For accomplishing effective motions men formed themselves together more and more into cog-wheels of organized flesh. Wheels meshed with central wheels of higher leverage and controlled in turn peripheral rollers to grind out whatever product implicated mass-motion could achieve.

The Newtonian concept of machine and of mechanical uniformity and law and logic is clear-cut, intolerant, admitting of no exceptions; it is supposed to be impressed from without, by superior nature upon inferior mind; it is alien to personality, and although it has an appearance of rationality this concept may be alien ultimately to reason itself.

Pistol shots at Sarajevo echoed on the telegraph cables. New aggregations started, new revolvings of human wheels. Masses of men and of munitions moved across the face of the earth.

The descriptive words that were used by the popular orators in each nation were honor, fatherland, democracy, courage, loyalty, God; but the modern categories, distance, time, mass, number, brute-fact, Newtonian machines, have no place for what is represented by such words; and the action was the moving of masses of men and munitions. The effective words were: Fix bayonets; Trench-mortars to destroy all wire by zero hour; Stretcher-bearers report to battalion headquarters; Green rocket means lengthen the barrage.

If a waiting cannon somewhere needed two thousand shells to kill a man, lights blazed all night in factories, miners delved as never before, in laboratories scientists sprang to relevant problems, bankers made entries in ledgers, legislators originated committees, freight-cars were shunted, and ships were crammed, and rolling caissons and floating magazines were filled again and again; and in Flanders or in Masuria or in the Apennines, in the North Sea, in the Congo basin, in the Pacific, along the Jordan, on the Marne or among the hills of the Argonne, a man was selected in the lottery of the salvoes.

(4) Contingency: Leibniz, Philosopher of Post-Modernism

Newtonianism's failure at Versailles: Lotteries are a phenomenon extraneous

to strict mechanical science—although in very recent physics, in wave-mechanics, chance phenomena are presented as everywhere fundamental.

A victory in the war was won by the Newtonian action and disintegrated by the subsequent and predictable extra-Newtonian random reaction. At Versailles, would-be engineers of a political world-machine envisaged their problems principally in Newtonian terms of space and time and mass and derivatives of these, in terms of number and of severely defined fact and law. They drew geographical boundaries. They defined terms of years during which vanquished territory should be occupied and monetary indemnities paid. They constructed paper constraints designed to keep opposition from developing an effective counterweight in men and ships and resources. Their legalism regarded law not as natural uniformities but as arbitrary commands laid by superiors upon inferiors.

No epoch is simple: in every age, even the modern, residues of older attitudes and promises of yet-to-be-realized primary points of view, exist. The Divine Comedy is nothing if not medieval, and yet we find Dante endorsing modern empiricism—"From this objection, experiment, which is wont to be the fountain to the streams of your arts, may deliver thee, if ever thou try it." Elsewhere he writes one of the earliest known references to our post-Newtonian theory of probability—"When a game of dice is broken up, he who loses remains sorrowful, repeating the throws, and, saddened, learns." If the same humility were emulated by European diplomats—who seem to have a talent for losing even with loaded dice—international relations to-day would be more propitious.

Not reasoned certainties but extra-rational contingencies disintegrated the Treaty of Versailles and made impotent the League of Nations. The narrow rationality of the framers made the contingencies certain.

Contingency in physics: Eighteenth-century satirical Voltaire had much to do with popularizing Newtonian rationalism as substitute for medieval faith. There is opportunity to-day, with excellent physical backing, for literary assault on a rationalism which fails to recognize the importance of contingency. In physics, Boltzmann and Gibbs, sixty years ago, following Carnot's earlier lead in thermodynamics, broke into new territory quite outside Newton's contemplation, when they began concretion of the mathematical theory of probability. The kinetic theory of gases is our classical example; Maxwell contributed to it: the motion of an air-molecule between and during collisions (neglecting subtleties of very recent wave-mechanics) is in detail Newtonian; but the billions of collisions per second of each of the one hundred billion-billion molecules in a cubic inch of air obviously can not be followed so, and the indefinitely diverse courses of the mutually disturbed molecules raise problems of a new order, which are met by introduction of the notion of probability.

The meaning of probability long has been subject of disagreement among the philosophically-disposed. Unquestionably, probability is no derivative of Newton's distance, time and mass. It can be measured by number, but only after an arbitrary convention is adopted as to what number shall stand for certainty; intrinsically it has no more to do with number than has space or time. Puzzling paradoxes are met if attempt is made to include probability in the domain of fact and law as Newtonians understand these. My own opinion is that probability represents an incidence in physics of the philosophical principle of "sufficient reason."

Origin of mathematical theory of probability: The principle of sufficient

reason was made by Leibniz, Newton's contemporary and consummate rival, a cornerstone of logic, but Leibniz's logic has had as yet no detailed development. When two dice are thrown, what is meant by saying that the dice and the throwing are fair? We mean that of the six times six possible combinations no one differs in likelihood from any other—double one, or "snake-eyes"; one, two; two, one; double two; one, three; and the rest. That is to say, we have *in*sufficient reason for supposing that at the next throw a particularly assigned combination will appear. The subsequent mathematics is mere enumeration of combinations.

The origin of the mathematical theory of probability is a curious passage in the evolution of ideas. According to references compiled in Todhunter's "History," Kepler and Galileo exhibited a little interest in problems of chance and combination; but Galileo's contemporary, Descartes, mathematician and philosopher, gave the subject no attention. Leibniz was definitely sympathetic toward it, but did not contribute much to the mathematics. Apparently Newton completely neglected theory of probability, although elegant mathematical theorems of his yielded important by-products for later application. The mathematical theory was founded, essentially, in correspondence which passed between Pascal and Fermat in the middle seventeenth century when Newton was a boy in his teens and Leibniz was four years younger. It is hard to explain the lapse of several score years which followed before problems of chance began to be studied again; apparently the mathematical atmosphere during the interval was too severely rational for chance to flourish.

First application of the theory to problems of physical science related to reduction of the effect of errors of observation by averaging. First work in this important field was in 1757 by Thomas Simpson, and although he was professor in a military academy his study dealt with measures in observational astronomy, not with dispersion of shots around a target.

The marine underwriters who during the late sixteen hundreds fell into the habit of assembling in Lloyd's coffee-house to ply their trade in risks did not wait for the tardy actuarial mathematics which helped to foster in the nineteen-hundreds a vast development in all kinds of insurance. This development is a unique characteristic of our times. To-day it is desire of average citizens for protection against risk of unemployment that outruns mathematics.

Many business men who even to-day are far from being masters of the mathematical theory of statistics rely nevertheless for their profits upon the recurrence of very unusual wants, a recurrence which can bring steady flows of customers to their doors or mailboxes only by virtue of the statistical steadiness which large circles of potential customers ensure. One such example is the enterprise of manufacturing glass eyes. The steadiness of rare circumstance which large numbers guarantee is an obvious notable factor in the continuing growth of cities and of all sorts of highly specialized metropolitan organizations.

Philosophy of Leibniz as possible influence on modernity's successor epoch: The fundamental ideas of modernity, it seems to me, reached full stature in Newton. Mathematical study of contingency is chiefly post-Newtonian, and its nineteenth-century applications in physics are definitely extra-Newtonian. The conclusion of the indicated syllogism is that the germ of modernity's successor-epoch, Post-Modernity, is already forming.

Thoroughgoing recognition of the importance of contingency leads to results far more important than the mere mathematical discussion of probability, more

important even than the grab-bag exhibition of equally valued trivial experiences and random petty images which is coming to constitute favored and not unpleasant technique in literature, art, ethics, education and politics.

To the acute mind aware of *contingency,* fact itself no longer is presented with the sharp distinctness which it has for Descartes—who, with Galileo, was source of Newton's own philosophy. Involved with every fact in the text-books is an indefinite regression of other facts which are implied and assumed in statement of the first. The nearer is a fact to the temporary limits of knowledge, the more implicated becomes this regression and the more blurred ought to be statement of the fact.

Bridgman of Harvard recently has emphasized this conclusion, but his post-modern position has as yet made small impression; nor would he be sympathetic, necessarily, with my further comments.

To Leibniz—whose philosophy is very different from that of his more successful contemporary, Newton—truth is necessarily just such a varying blur as Bridgman describes in "The Logic of Modern Physics": ranging from clearer and more distinct to clouded and obscure; never utterly sharp, never wholly blurred. For Leibniz the minds which reflect truth form a similar hierarchy.

I hope you have been lured out now to the frontiers of knowledge—of philosophical knowledge at that, which is by all odds the vaguest. Awareness of contingency is intimately related also to awareness of the possibility of *control:* brute-facts lose their implacability for a society in which free precise scientific description of conditions is followed by courageous invention and energetic enterprising.

To society, to minds at this level, nature shows a different aspect than to Newtonians: distance, time, mass, lose significance, except as abstractions sometimes useful; number is replaced by intensity; all apparently isolated facts merge, I think, into what Lovejoy in just-published lectures names "the great chain of being," the postulated hierarchy of all things, which has stimulated minds in every epoch before the modern. Dante describes it thus—"All things whatsoever have order among themselves. . . . In the order of which I speak all natures are arranged by diverse lots more or less near to their source." This is exactly the standpoint of Leibniz; who elaborated the position further than his predecessors: in any given fact all other facts are implicated, more or less distinctly, but without destroying its independence. The universe for him is constituted of *monads;* and each monad reflects the universe, with clarity proportionate to its own degree in the "chain." What for Newtonians is arbitrary law is replaced to Leibniz by inner *harmony* which the monads share, according to their degree, and which is their only interrelation.

A corollary of this Leibnizian philosophical postulate is that all the subjects which scholars study can be made, notwithstanding their unique content, to exhibit more or less distinctly a common logical pattern. The search for thorough-going analogies of form becomes then a notable method of research, supplementing our intolerant modern empirical testing.

To Leibniz, not atoms bobbing through space in time's thin stream and not inhumane facts related together only quantitatively by illogical laws of nature, but monads are the Real. A monad is embryonic personality, its quantity perhaps is clarity as its energy is sympathy.

Leibniz was Newton's fertile peer in pure mathematics, his scarcely recognized and at the time unsuccessful opponent in the interpretation of physics, his great superior in systematic philosophy: whose ubiquitous continental genius

was participating in every linkage from medieval to modern, when Newton, close islanded in Cambridge and London, was calculating unsurpassed quantitative agreements, reforming English coinage and grinding telescope mirrors. Newton acted out his logic in his study and his laboratory and never wrote of it; Leibniz wrote of his, and it was too subtle for effectiveness in that raw time. Newton's logic has been the logic of our age; but modernity is decadent.

Leibniz's long-disregarded logic is a challenge to every competent scholar who is willing, in order to advance his special field, to risk contributing also toward broad interests of society. If it can be proved that exact and apparently widely separated disciplines—such as thermodynamics and jurisprudence—can be set forth to some extent in a common symbolism, then specialism becomes path to universality. Resultant intensification of learning's humaneness will end modernity.

If it be objected that this suggested philosophy for post-modernity is too closely linked with pre-modernity, which is to say, medievalism, no one can assert that philosophy-of-history—the great dynamics which has been imagined, perhaps too romantically, as describing the succession of society's primary passions and motions—is a subject in which reliability exists. For what the over-simplified analogy may be worth, however, I would reply that recognized first stirrings of our own epoch, Post-Medievalism, came with the "revival of learning" when scholarship gained fresh vigor from fresh contact with problems which had been neglected since the close of the ancient or pre-medieval period.

Decadence of Modernity: Newton died five years before George Washington was born; he ground the first reflecting telescope, and these mirrored the difficult stars scarcely more distinctly than Newton's mind reflected modern triumphs of technology. Galileo's condemnation, Kepler's discovery of numerical harmony, Tycho Brahe's exile for his shameful interest in astronomical observation are three centuries back and more. It has been long since science began as young revolutionary in a hostile world. Space, time, matter, number, fact, mechanical law—these we sought and these we have been given; but Tycho's poetry, Kepler's free imagination, Galileo's daring independence—these remain uncommon.

It is in the nature of a boom to overshoot just valuations, and success of Newtonian thought in relation to things material is as splendid a boom as history records. There are more workers in science by far than ever before; there is no sign of approaching lack of productivity among them—if productivity be judged by their own specialized standards. I dare say that theologians three centuries ago who tried to stamp out radical empiricism considered that their own old dialectic remained satisfactorily productive, for within their bounds of recognized orthodoxy permissible disagreements existed in detail and served for endless delightful arguments among the brotherhoods. Such argumentation had passed, however, its marginal utility as regards its human value.

On the other hand, no competent student of natural science, I think, however competent or incompetent he may be as critic of civilizations, will support the idea that scientific investigation should presently cease or slow down, that there should be now a moratorium on science. It is not science but Newtonianism that is under indictment for many of the unpleasantnesses of our times.

(5) Post-War Technology and Physics

The first world war and the following booms and depressions in business were only incidents in the continuing drama of onrushing science and technology.

After 1914 the speed of airplanes trebled, and their loads and non-stop range doubled and doubled again. Buildings and ships grew bigger and bigger, along with losses of stockholders. Automobiles were fabricated in number beyond belief, as this American mass-industry followed the lead of Henry Ford, who had been first manufacturer in the world to pose his problem purely in Newtonian terms of the speeding assembly line. Photography, which already had begun to move, projecting time and space in melodramatic masses of light and shade, moved more gracefully and expensively to nightly audiences of increasing scores of millions, and no longer in dumb-show as vacuum-tubes were perfected and electricity became sound's docile slave. Radio put into every kitchen the authentic voices of kings. Mountain-ranges were stripped of remaining forests in order to satiate printing-presses.

Of these externally productive years a future historian may say, "It speaks a marvel for the adaptability of man that insight should not have been even less effective than it was, so burdened and so isolated did minds become in this inchoate mass of literacy."

Books were publicly burned and their authors sent to internment-camps. Churches and cathedrals were converted to secular uses.

In physics the genius of Einstein adapted differential geometry of many dimensions to fundamental description of dynamics; already in 1905 he had exhibited time as a sort of space; and in 1915 he resolved the distinction between inertial and gravitational mass—which always had puzzled the Newtonians—making mass also a property, a warping, of his complicated space. This "general relativity" was astronomically verified, with justified publicity. Pure mathematicians had been operating, for the most part, in a vacuum, almost ever since calculus, which is very generally applicable, had been invented by Newton and Leibniz; here in relativity are fresh applications, although of far less practical significance. Planck in 1901 and Bohr in 1913 had led, with less acclaim, another successful, and to physicists more interesting, departure from Newtonian methods in dynamics, in the theory of radiation and atomic structure. In this movement also Einstein had an important share; during the nineteen-twenties it was the chief activity in physics; Heisenberg and Schrödinger and other theoreticians contributed powerfully, and a new subdivision, "wave-mechanics," was founded. In this discipline probability seems to play a chief rôle, and scant shrift is granted "classical" ideas of Newton and Maxwell. Overtures have been made with a view to reconciling wave-mechanics with relativity, without result as yet. Experimental interest in the laboratories now has shifted center of intensity to "nuclear physics," with growing refinement in the high-vacuum and high-potential engineering.

RIVER AND SEA

By W. E. ALLEN

SCRIPPS INSTITUTION OF OCEANOGRAPHY OF THE UNIVERSITY OF CALIFORNIA

MY first direct acquaintance with river problems occurred in 1912 when I began my investigations of plankton (floating organisms) production in the San Joaquin River in California. In 1917 my activities in plankton research were transferred to the Pacific Ocean. In succeeding years I have wished again and again that I could repeat my river investigations under the guidance of my wider experience and knowledge. In connection with the thoughts leading to such wishes I have tried to imagine some of the results which I might hope to get. I have also given much thought to problems of river plankton as related to problems of ocean plankton and to the influences exerted by one upon the other. As a result I feel that some of the many interesting and important features in these groups of natural phenomena deserve attention and discussion.

Of course, we all know that there is a positive continuity in the existence of water on the earth and in the air, but it is not likely that any of us remember that point very frequently or that we think about it very definitely. Perhaps it is not necessary that we should, unless we believe it to be entertaining or profitable to examine natural conditions from every view-point. However, I am tempted to try to discuss water in a way slightly different from ordinary.

In the first place, I wish to emphasize the fact that water tends to be absorbed by the air. We are so accustomed to seeing water flowing in a liquid stream that it is difficult for us to appreciate the fundamental importance of air in its transportation. Under the simplest conditions occurring in nature a mass of air lifts a load of water from the sea (or other large body), carries it a short distance vertically or horizontally and drops a part of it. But, with the rarest exceptions, it is only water that is transported by air in this way. When the load of water is lifted all dissolved and suspended substances are left behind. Momentarily, at least, the surface of the ocean at the loading point becomes slightly more dense because of the solid residues not taken. If the load is dropped again on the ocean a reverse change takes place momentarily and the surface density is lessened.

In cases almost as simple the load of water taken from the sea is carried over land until proper conditions lead to its loss, but the results are far different. Most evidently, the sea has incurred an increase of solids as compared with its fluid mass, a burden from which it can get no relief except as it is able to drop parts of its load. Less evident, but far more important, are the results on land. There the water released from the air may be involved in several different processes of change. Most notably, it may be used by organisms to sustain life, it may be absorbed by solids which it helps to disintegrate, it may dissolve substances from the surfaces of solids, it may absorb gases, it may carry many kinds of substances in suspension, it may push objects that it can not carry, it may collect into pools or larger bodies, or it may be quickly reabsorbed by the air and carried to some other place favorable for unloading.

Immediately, or indefinitely later, any particular air load of water contributes to the formation of a stream after it is discharged over land. Most of it may be again absorbed by air before a stream of considerable size is formed (in deserts even large streams may disappear in this way), but the remainder flows on toward a final union with the sea. Before the

time of this union, perhaps throughout its journey after the time of discharge from the air, this remainder has been carrying burdens not always the same either in amount or characteristics. Joined with it in the river are remainders of other air loads, each with its own history of travel and of burdens accumulated or changed or released. In any case, most of the water flowing into the sea as a river has had a history so complex as to almost surpass our imagination.

Sooner or later after meeting the ocean river water loses its stream identity. It loses parts of the burdens peculiar to it and it acquires other burdens peculiar to sea water until the union is complete and it has become again an indistinguishable part of the sea. Under favorable conditions some large rivers retain their identity as streams of fresh water for many miles after flowing into the ocean. Others may have the union so far advanced while flowing through bays or other coastal indentations that there is no distinction between sea water and river water at the final entrance into the sea. In some regions rivers are constantly contributing to the sea. In others there may be intervals of months or years between times of flow of fresh water into the sea from local rivers. In Southern California a number of rivers are dry for months of nearly every year.

A strongly flowing stream carries much suspended material which may be deposited as a delta or alluvial fan on land if the lower reaches of the bed traverse level or nearly level territory. According to conditions this delta may be extended indefinitely under the sea or a branch of the sea. In any case the less buoyant particles will be deposited first, on land in some cases, near the shore in others. In definite progression according to lack of buoyancy other particles will be deposited in successive distances from shore until all or nearly all sedimentary material has been lost. Thus the river water loses one of its distinctive burdens very rapidly in most cases.

Probably the simplest form of such conditions is shown by the runoff of temporary streamlets from the hills at the Scripps Institution of Oceanography at La Jolla, California, after heavy rainfall. Inside the breakers the water is distinctly muddy in appearance, not only because of the size of the suspended particles but also because of their relatively high abundance. Beyond the breakers the color is somewhat lighter and the fluid looks thinner because the heaviest particles have been deposited and because the muddy stream water has been diluted with sea water through thorough mixing in the breakers. Further seaward a gradual reduction in muddy color occurs until it may be entirely lost at a distance of a mile or less. As the last trace of eroded material disappears from sight one may be tempted to assume that significant influence of the streamlets has reached its limit, that fresh water has become sea water and that its contributions to sea water have been completed.

I believe that this assumption is untenable. Admitting that soil particles have been scattered so widely by dilution that their presence is not visible, there is still the probability that those of more nearly buoyant form or composition may be supported by water movements until they are many miles away from their point of entrance into the sea. Some of them may go into complete solution or decomposition without ever sinking to any notable extent in sea water. Furthermore, it may be supposed that a particle of fresh water may merge into sea water without losing its physical identity. By losing some of its fresh water load and taking on some sea water load it may change its general relationships, but it need not be decomposed in those processes and it may retain some items of its fresh-water load. For example, if the particle of fresh water carries a trace of iodine too small for satu-

ration it may retain that item indefinitely. In that case, it may contribute that much iodine influence to accompany sea water in some area far from its source which has been reached through the vagaries of oceanic circulation. If such extensions of influence be possible from temporary streamlets they are far more nearly possible from the flow of rivers into the sea.

To the student of life in the sea the problems of the influence of rivers and other inflowing streams seem very intricate and difficult but of the highest importance. Some years ago Gran and other observers of marine plankton plants favored the idea that runoff from land contributed substantial amounts of nutritional substances to the sustenance of plants in the sea. More recently, apparently, Gran has abandoned this view, although he has shown experimentally that added traces of certain substances such as iron have much to do with invigorating or accelerating processes of growth and reproduction in marine plants. Still, I do not know of any direct proof that even the nutritional contribution of runoff is negligible. I do not believe it to be so, although I agree that nutritional results may not be direct and immediate. A soil particle, organic or inorganic, useless to plankton plants as it enters the sea at the shore, may be highly useful to them after a period of disintegration or decomposition in sea water with or without the action of marine organisms. It is also true that some particles may not be useful to plankton plants without the presence of activating substances or other complementary conditions.

My indulgence in the foregoing elementary discussion has been due to my desire to show that my view of the characteristics of rivers and of the phenomena of their existence is considerably different from that of most students of river waters. As an oceanographer, not only am I more than ordinarily interested in rivers as individual streams but also in the "system" peculiar to each river, in the whole group of eroding and transporting waters moving to the sea. My own river studies were made in only two localities on a single river, and the results seem pitifully inadequate in consideration of what I would like to know about that river as a whole. One outstanding point in my memory of my observations is that the conditions of plankton production (and of the river in relation to them) were radically different at Stockton, California, and at Fresno, California. And I know from cursory inspection of other sections that each of them must have been also widely different. When I speak of the San Joaquin River I visualize the section at Stockton, with which I was most acquainted, but I know that the visualization does not correctly represent that river as a river. This is especially true when I think of the relationships of this river to the sea, a relationship complicated by the fact that other bodies of water intervene between them. But, ignoring this matter of mergence with other waters before reaching the ocean, I wish to mention a few ideas relating to the river alone.

So far as the observations near Stockton were concerned it appeared that in the flood waters of summer little, if any, plankton existed. A little later, in the relatively sluggish waters of late summer and early fall, it was just as evident that abundance of plankton was very high. Considering plankton production alone in the lower reaches of the river, it is surely certain that there were marked differences in the contributions made by it to the sea at high water and low water stages. Can we rightly avoid consideration of the influences of these contributions with the excuse that all traces of their identity are lost in the long passage through the bay to the ocean? If we can not rightly do so, we should admit that conditions in any part of the San Joaquin

River system have fundamental interest for students of the sea because any part may be the source of some contribution which helps to explain some particular observed condition in the sea.

Viewing the San Joaquin River system as a whole one may imagine that a particle of iodine (or similar substance) captured by a particle of water in the high Sierra may be carried without change down the mountain slopes, along the valley floor and through San Francisco Bay to the ocean. Perhaps it is less likely that a particle of calcium or iron may be carried so far without change. Some plant may remove it here, some animal use it there, and it may finally reach the sea as a component of some organic waste. Surely similar statements may be made concerning the possible river history of limitless numbers of different kinds of materials. And the numbers of changes and kinds of changes in these materials will have much to do with the character of the influence of any one of them or of all of them after reaching the ocean.

Although a marine investigator might not be always aided in his understanding of conditions observed in the sea by having a knowledge of occurrences in all parts of a river system, he would be interested if it could be shown that a series of phenomena in upper reaches of the river had traceable influence on the contributions finally made by the river to the sea. If a shift in these phenomena in the high mountains in a certain year leads to great productivity of plankton in the lower river and so either reduces or augments the contributions favorable to plankton production in the sea he may be directly and positively interested in them. If a migrating stream bed of some tributary of the river reaches a new deposit of salt or other soluble substance, it may have enough influence on both river and sea to change the amount and character of plankton production in certain localities in a particular year. A river change of this kind would be just as interesting to a marine biologist as to a specialist on river studies.

Observations on phytoplankton in the eastern Pacific, made by the Scripps Institution of Oceanography, have shown positively that in the whole range from Alaska to Peru, from frigid to tropic waters, there are localities which are heavily productive and other localities which are poorly productive of phytoplankton. No direct relation of river runoff to the showing of either type of locality has been found, as yet, but it surely is possible that conditions of land drainage account for at least some of these phenomena. In one locality some stimulating or accelerating substance may be acquired from river water in a way to increase production. In another locality such material may not only be lacking, but enough of some inhibiting substance may be present to limit production.

In either case the marine biologist might know more about production problems and many other problems of the sea if reliable information concerning river systems as wholes could be found. It is not enough to know that the water at the mouth of the river contains so much calcium, so much magnesium, so much potassium, so much sodium and other substances easily recognized. So far as marine organisms are concerned, it may be more important to know the availability of less abundant elements or compounds or of an indefinite number of organic compounds. Lacking opportunity to conduct chemical analyses in either number or refinement sufficient to show these things, something of the influential differences in river waters might be surmised through knowing river history and river characteristics in all its parts.

At any rate, it is my belief that rivers have enough influence upon the sea to deserve more attention than they have received, particularly in relation to biological phenomena of the sea.

THE CONTROL OF RAGING WATERS

By Dr. A. F. WOODS

DIRECTOR OF THE GRADUATE SCHOOL, U. S. DEPARTMENT OF AGRICULTURE

A CENSUS has never been taken to find out why people select a river bottom as a place to live when higher ground is available. But we know that flowing waters have an unmistakable appeal to those who live in contact with them.

It is a kind of hypnotic effect, a dream-like projection of self to the distant places to which the waters are flowing. These dreams bring enchantment to the Huckleberry Finns who dwell by the river.

There is always something going on by the river; fishing, hunting, boating, and when the storms come or the winter snows suddenly melt, there is the hurried preparation for floods and, if necessary, a temporary move to higher land. All this furnishes some excitement.

When the floods are more or less local in their origin the river-wise usually know when to move to higher land. But when the waters come from large and distant areas, local calculations fail. Agencies in touch with the larger area must furnish the information necessary to enable the isolated communities to protect themselves. Only the state or federal government can do this.

In our great drainage basins, like the Ohio Valley, the Missouri Valley and the Mississippi Valley, in the earlier days before the forests were removed from the tributary waters and before the land was broken into farms and the natural vegetation cover destroyed, the river channels were deeper and more of the water was absorbed by the ground. The flow in the streams and rivers was more uniform and floods less common and less destructive.

THE RIVER MINES UNDER THE BANK AND CUTS IT OUT.

BANK EROSION ON THE MISSOURI RIVER.

UNTIL THE PROTECTION WORK WAS PUT IN BY THE GOVERNMENT THE ANNUAL LOSS WAS MORE THAN 100,000 ACRES OF THIS FINE FARM LAND.

The river-wise could plan with greater certainty.

Inviting the Floods

For nearly a century the people inhabiting these great river basins have been engaged in a program of cutting down the forests, breaking up the prairies, draining the swamps and wet lands. Water has been treated as something to get rid of in the quickest way possible. The result is that the richest top-soils have been washed into the streams and rivers and carried on to enrich other areas or on out to sea. The heavier materials gradually fill the river bed, thus reducing its carrying power and increasing the danger of overflow. When torrential rains come the sand and gravel are carried out to cover and destroy fertile lands.

The worst conditions on a large scale are found in the lower Mississippi, Ohio and Missouri Valleys and tributaries south. Below the confluence of the Ohio and Missouri the areas covered by floods have been large.

In the Early Days

But in the early days before flood protection programs were developed, the water spread out over large areas and did little permanent damage. I have frequently seen small creeks tributary to the Missouri, as far north as Omaha and 50 miles from the Missouri, become in a few hours a mile wide with back water from the Missouri. This might last for a few hours or sometimes several days or weeks. The top-soil was more or less washed from cultivated lands, but most of the area being in native wild prairie grasses, the soil was not disturbed. Nearer the Missouri more sediment was deposited wherever the water was retarded in its flow, but this sediment was largely rich soil that added to the fertility. The river bottom soils were then and are now very rich with a deep deposition of water-carried material. Much of the time these soils can be cultivated. They produce large yields of corn, wheat and hay.

When the Floods Come

But when the floods come the raging waters may destroy everything. Even though the waters may be confined within the banks, the banks themselves may be washed away by the rushing waters. New channels are formed, and what was once fine farmland disappears in the river. Buildings, fences, roadbeds and railroad bridge abutments may be destroyed as the rushing waters eat the bank away. The action is so rapid that one watching may see great chunks of earth weighing many tons topple into the water every few minutes.

Discovery of a New Plan of Control

Many kinds of schemes have been tried to prevent this bank erosion, but nothing was found permanently successful until a plan was devised by a man who owned some of these riverside farms along the Missouri and had watched them float away down the river.

The man was Mark W. Woods, of Lincoln, Nebraska. The story is interesting and is worth telling, as it has now become standard engineering practice where similar problems of bank protection are involved. As already suggested, the objection to the old methods was their failure to withstand the digging power of heavy floods, therefore requiring frequent replacement. The expense involved was prohibitive, especially in the case of the small landholder.

Mark was fond of hunting. Each year when the season came he spent some time on the lower Platte, which is a river of quicksand with many shallow pools furnishing food for ducks and geese. On the particular occasion to which I refer he was on a hunting trip with General

—*Courtesy Field and Stream*

GENERAL CHARLES G. DAWES WITH MARK W. WOODS COMING IN FROM A DUCK-HUNT.

Pershing and the superintendent of the Burlington Railroad. They were hunting near where the Burlington Railroad was constructing a bridge across the Platte. It is well known to engineers that it is very difficult to secure adequate foundations in quicksand. The Burlington superintendent invited General Pershing and Mark to inspect the bridge project. The work of placing foundations appeared to be proceeding with less trouble then under ordinary favorable conditions. Great concrete piles weighing many tons and 75 feet long were placed by a great crane where the engineer desired to sink them and in a few minutes they were out of sight below the bottom of the river. To any one familiar with driving piles in quicksand this was an eye-opener. Mark was interested at once and, finding that the chief construction engineer, Mr. Bignall, was a next-door neighbor and friend, he asked for an explanation. Mr. Bignall explained that he was using a specially constructed pile which he had devised and patented. It consisted of reinforced concrete, with a large iron pipe extending lengthwise through the center with an attachment for a pressure pump at the upper end and a steel cutting shoe at the lower end, the outlet of the pipe at the lower end extending through the center of the shoe so that the water under pressure could dig the hole for the pile to occupy. Side off-shoots were provided on each side about two feet apart to keep the sides free from sand pressure. As long as the pump pressure, about 150 pounds to the square inch, was maintained, the pile

could be churned up and down to chop through hard pan or soft rock, until it reached the depth desired; then the pump pressure was removed, the sand settled in and the pile was in place permanently. The piles went down like pencils in cheese.

Mark thought right away, "Here is a method of permanent anchorage that might be adapted to riverbank erosion control."

A New Use for the Bignall Pile

He ascertained that the pile was being used only for bridge construction, by the Burlington, where ordinary methods could not be used. The Burlington paid a small royalty to their engineer for the use of his patent pile. It did not take Mark long to arrange for the exclusive use of the pile for other purposes on a royalty basis. He confided his plans to General Pershing, who was interested and asked to be kept advised as to how the plan worked out. Mark then called upon the government engineers in charge of work on the Missouri. He asked for permission to place brush retards in the river where the former line of his property had been, with the idea of causing sedimentation of the mud and the building back and further protection of his land. The engineers were very skeptical of the success of the plan. They said: "You will spend a lot of money. The plan may work for a while but when a big flood comes all your work will be lost."

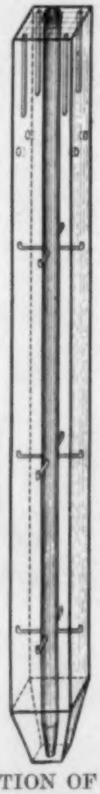
Mark insisted that he wanted to give it a trial and the engineers consented. He rigged up a flat boat with a heavy crane and the other necessary equipment. He then cut cottonwood trees, which were plentiful in the bottom lands and tied them in large bunches with galvanized cable and hauled them by tractor

—Courtesy Field and Stream

GENERAL JOHN J. PERSHING AFTER A DUCK-HUNT (LEFT).

and anchored them to the concrete piles sunk by the method described, far below the digging power of the river. These tree retards were placed in lines extending from the river bank to the former property line. The retards were forced down practically to the bottom with the tops extending up to catch flood waters.

They were placed at intervals of a few hundred feet, forcing the currents of the



THE CONSTRUCTION OF THE BIGNALL PILE.
THE LOWER END MAY BE FITTED WITH A V-SHAPED STEEL CUTTING SHOE IF DESIRED.

river into the main channel. The slowing down of the water caused sediment deposition. In a few weeks there was a mud flat where before water had been flowing.

Floods Rebuild the Land

Each flood built the fill higher. Fortunately for this test maximum flood periods developed during the year, each adding its load of mud. By the time of the next hunting season the lost land was practically recovered and General Pershing and the Burlington superintendent were invited to inspect the project. They were greatly impressed, because much of the government work on the river had been washed out by the same floods that had only improved this project. General Pershing invited army engineers from Washington and from stations on the Missouri and Mississippi Rivers to inspect the project. The engineers were impressed but not convinced. They knew of some situations where they felt that the plan would not work. One in particular was where a great whirlpool was caused by a side current of the river striking a railroad bridge foundation abutment. It was digging a deep hole near the bridge foundations. Trainloads of rock and even old steel cars had been dumped into the hole, but without avail. It looked as if the bridge were doomed.

The engineers said to Mark, "If you can stop that whirlpool and fill up that hole there will be plenty of work for you to do in controlling Old Man River."

It looked like a hopeless job, but Mark studied the trend of the river, found where a few retards might deflect the main current into a channel away from the abutment. He placed these retards. The current changed, as he had hoped it would. The whirlpool was eliminated, the hole was filled by the river itself, and the bridge was saved.

A new method of permanent bank protection was thus demonstrated which was inexpensive compared with the results achieved and capable of very wide adaptation. A type of pile was developed for making solid concrete dike facing. One side has a V-shaped notch and the other an inverted V to fit the opening. The piles are sunk side by side thus locked

together. The work is rapid and permanent and comparatively inexpensive, considering that other types of protection are not permanent. Many miles of dikes on the lower Mississippi and Gulf Coast are now thus protected.

When the water is held within bounds it digs its own channel deeper, aiding navigation and facilitating run-off.

A National Program

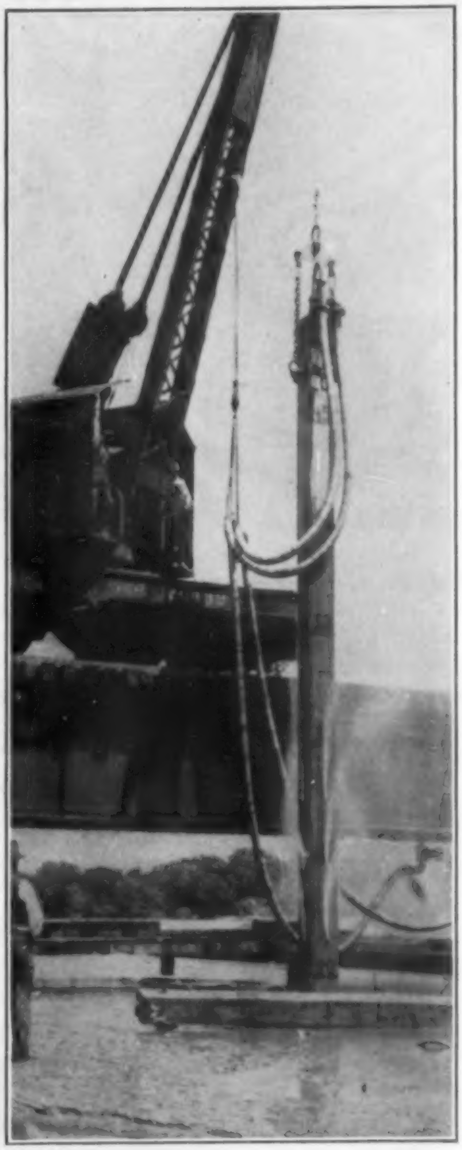
The great erosion control programs of soil conservation reaching back to the farms, forests, foothills and mountains are now recognized as the first line of attack on the flood control problem. Bank and dike protection with reservoirs, lakes and spillways and deepened channels are the final line of defense against raging waters.

The scientific aspects of flood control and soil and water conservation are described in a clear and interesting way in three papers presented at the Rochester meeting of the American Association for the Advancement of Science in June, 1936.[1] A careful reading of these papers will make it clear that the great programs of conservation of soil and water are fundamental to the continuance of our civilization. Great and prolonged drouths and raging floods make us awake from our slumbers and study causes and devise methods of protection.

These studies have shown that while losses almost beyond computation have taken place in a few generations, we can by wise planning and vigorous action in a considerable measure restore part of what we have lost.

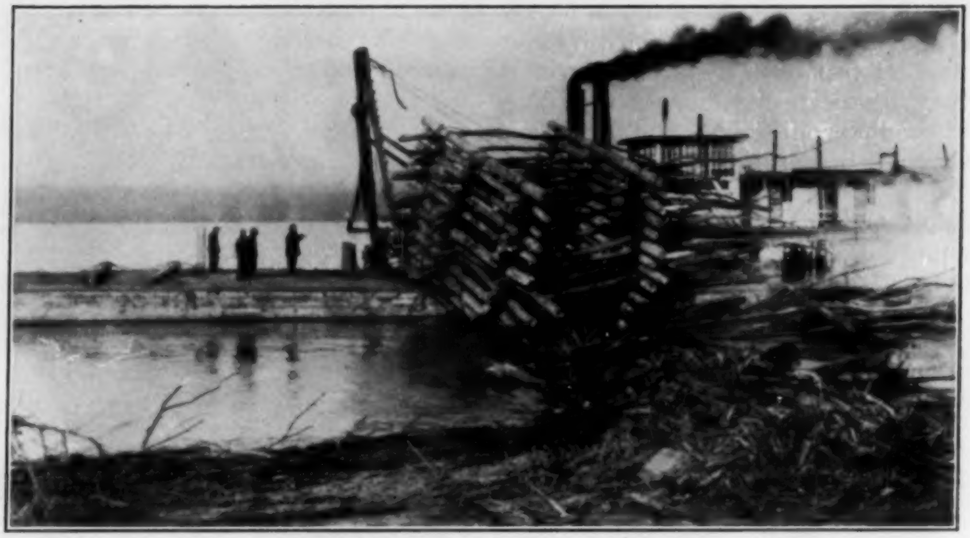
We can restore the underground water reserves by controlling run-off and in so doing prevent soil erosion and loss of fertility. The stream beds are not filled

[1] Occasional publications of the American Association for the Advancement of Science, No. 3, October, 1936. Supplement to *Science*, Vol. 84. Price, 50 cents.



THE ORIGINAL BIGNALL PILE

USED BY THE BURLINGTON RAILROAD IN CONSTRUCTING A BRIDGE OVER THE PLATTE RIVER AT ASHLAND, NEBRASKA. THIS FURNISHED THE INSPIRATION TO TRY THIS PILE AS AN ANCHOR FOR PERMANENT RETARDS TO PREVENT RIVER BANK EROSION, AN EXPERIMENT THAT PROVED TO BE SUCCESSFUL.



PUTTING IN A SECTION OF RETARDS
WHICH ARE ANCHORED UP STREAM WITH THE BIGNALL PILE SUNK BELOW THE DIGGING LEVEL OF THE RIVER.

with eroding soil and can therefore carry their load of water with less danger from flood. Lakes and reservoirs are being constructed to store excessive water and feed it gradually into the subterranean supplies and into the streams. Water for irrigation and for power development becomes more uniformly available. Fish, waterfowl and other forms of wild life breed more freely and become again a source of profit and pleasure. In the larger streams, like the Missouri, Missis-

COMPLETED RETARDS,
ONE IN THE FOREGROUND AND ONE IN THE DISTANCE. IN 90 DAYS THE RIVER BETWEEN THESE RETARDS WAS ALL FILLED IN AND IS TO-DAY GOOD FARM LAND.

sippi and Ohio, transportation takes on new life not only by water but by rail. This has been amply demonstrated by the projects on these rivers.

The records show that from 1900 to 1925 the waterway traffic in the Pittsburgh district increased 32,000,000 tons, and the railroad traffic in that district increased 116,000,000 tons. It is evident that the lower transportation rates brought about by water competition have stimulated industry as a whole. Of the total tonnage handled by the barge lines, 85 per cent. is also handled for part of the haul by the railroads.

On the Missouri River, bank protection, channel dredging, where the river does not do the work, have been largely completed as far north as Kansas City. The construction of the project to Sioux City is now well under way.

The great Fort Peck reservoir now well along towards completion is an important factor in this general conservation and development project in the Missouri River Valley. According to former Governor Arthur J. Weaver, of Nebraska, the Fort Peck project was authorized to equalize the river flow in dry years and periods of normally low water, to protect navigation and insure water for the six million acres now under irrigation and at least 4,000,000 acres that must eventually be irrigated. Besides taking care of irrigation this reservoir, by storing flood waters, will guarantee a dependable and regulated nine-foot channel at low water from Yankton and Sioux City to the Mississippi River. Transportation cost on a nine-foot channel is but half the cost on a six-foot channel. This is the standard depth maintained in the controlled areas of the Ohio, Illinois and other rivers of the Mississippi system. The Fort Peck project will cost about $80,000,000. It is said to be the largest earth fill with concrete face in the world. The maximum height is 240 feet above stream bed. The storage capacity at normal pool level is twenty million acre feet or about six times that of the Norris dam in Tennessee. The pool will be 182 miles long with 2,000 miles of shore-line and will present a water surface of 242,000 acres.

This should change the whole aspect of life in one of the great dry-land areas. It is only a sample of what may be done in many other places and in fact of what is under way in many areas.

When these great programs are completed, Old Man River will no longer be feared. Transportation, water power, fish and wild life will thrive again, and the soil, the basis of our food supply, will be conserved for all time to come.

The river will be what it used to be—a source of wealth, power and inspiration.

EXPLORATION IN THE CHOCÓ INTENDANCY OF COLOMBIA

By W. ANDREW ARCHER
SENIOR HORTICULTURIST, U. S. DEPARTMENT OF AGRICULTURE

THE Chocó Intendancy, an area of some 18,600 square miles, populated mostly by Negroes and Indians, lies in the northwestern part of the Republic of Colombia, hemmed in on all sides by mountain ranges, with the low central portion of the Atrato basin drained by a network of rivers and tributaries. Quibdó, the capital, is most accessible by river boat up the Atrato River from Cartagena, although a few travelers make the journey from Buenaventura by river boat and dugout. More recently it has been possible to enter in a much shorter time by way of airplane. From the neighboring department of Antioquia there is a six-day trail made by pack train, and it was by the latter mode that the author entered.

This trail, leaving El Carmen, follows along the mountain ridges (Fig. 1), thus escaping all the larger rivers and the impassable swamps and jungle, but at best the route is precarious and tedious, oftentimes leading through stretches of boulders or scampering up rocky inclines at the mountain streams. Once within the domain all travel is by necessity in small dugouts (Fig. 4), by which one can reach slowly and perilously nearly any point.

Historically Cordoba[1] and Alvarez[2] indicate that Balboa discovered and ascended the Atrato in 1511 and that the early Spaniards were attracted to the Chocó in search of gold and later established small settlements in order to work the mines by aid of Negro slaves. Pirates, too, were drawn to prey on the rich cargoes and deposits of the Spaniards; in fact, the filibusters, Cook and Coxon, are said to have navigated the Atrato as far as Quibdó in search of plunder.

At the height of the Spanish exploitation the annual yield of gold was nearly a million dollars, but the liberation of the slaves terminated all organization and the country straightway declined, but nevertheless great quantities of gold and platinum still exist, although in a condition requiring modern methods of extraction. The latter metal occurs in greater abundance and brought unwonted prosperity to the descendants of former slaves during the boom prices of the world war.

The climate is no inconsiderable barrier to extensive exploration; the few outsiders who have heard of the Chocó will relate tales of heat and fevers, and although the reputation thus held is fanciful to a degree, at the same time justification is not lacking. For instance, the country lies near the equator and a major portion has only a slight elevation above sea level; but even so the traveler probably suffers no more from heat than he would during an average summer in an eastern city of the United States. True enough, under the tropical sun perspiration flows at the slightest exertion, but the vast regions of green jungle, the numerous streams and the copious and frequent rains afford considerable relief. Around Quibdó the mean temperature is about 84° F., this figure being remark-

[1] Francisco Cordoba M., "Nociones de geografía e historia del Chocó," pp. 25–32. 2d ed. Quibdó, 1929.

[2] Jorge Alvarez Lleras, "El Chocó," pp. 16–18, 23. Bogotá, 1923.

ably constant for all the months of the year.

Admittedly our temperature and rainfall data are quite fragmentary, but since no other observations are available they would seem worthy of inclusion here. They were made by Señor Rudolfo Castro, in connection with the construction of the Quibdó-Bolívar highway, which eventually may connect the Chocó with the neighboring Department of Antioquia.

From these data it would appear that the area about Quibdó receives an annual rainfall of over 450 inches, higher by some 127 inches than Buena Vista and by 178 inches than Andogoya; areas now holding the highest records for North or South America.[3] Treadwell[4] states that the rainfall is "180 inches distributed through the year," while Miller[5] says that the annual precipitation is 400 inches, but no authority is cited for the data in either case.

Quibdó, at 175 feet above sea level, is 80 feet lower than Andagoya, while both lie about 40 miles from the Pacific Coast, although the former is about 40 miles further north than the latter and is separated by an extension of the Andes which divides the sources of the San Juan and Atrato Rivers. Quibdó is separated from the coast on the west by the Baudó River, while on the east a high range of the Andes is but a few miles distant. Altogether there is probably some special topographical relation of the Quibdó region conducive to the enormous and constant rainfall, but definite records and

FIG. 1. CORDUROY TRAIL
ALONG A MOUNTAIN RIDGE TO THE CHOCÓ.

observations must await some future geographer.[6]

Under such humid conditions it might be expected that the natives would suffer the consequences of violating the more fundamental laws of sanitation, but such remarked paradoxically that the Chocó was the healthiest place in the world, although all the accepted rules of sanitation were ignored, yet with none of the usual ill results attendant upon such flaunting of cleanliness.

While the diseases of the country are numerous,[7] it seems that most, *i.e.*, aside from the great scourges, malaria, tuberculosis and rheumatism, are due indirectly to malnutrition. Typhoid or dysentery are scarcely known; but this may be due to the use of rain-water for beverage purposes. To attacks of ma-

[3] W. W. Reed, *U. S. D. A. Monthly Weather Review*, Suppl. 31, pp. 1–21, 1928; P. C. Day, *U. S. D. A. Monthly Weather Review*, 54: 378, 1926.

[4] John C. Treadwell, C. R. Hill and H. H. Bennett, U. S. Dept. Commerce, Trade Prom. Ser. 40, 1926.

[5] Leo E. Miller, "In the Wilds of South America," p. 64. New York, 1918.

[6] Jorge Alvarez Lleras, *op. cit.*, pp. 7–12, 76–79.

[7] Frederick Collins, 45th Cong., 3rd Sess., Sen. Exec. Doc. No. 75, pp. 115–118. Washington, 1879.

FIG. 2. MAIN STREET
AT QUIBDÓ, SHOWING MARKET DAY CROWD.

laria the natives apply loosely the terms "*la gripa*" or merely "*la fiebre*" (fever). My periodical prostrations were diagnosed by the local doctors as due to a usual acclimating fever, but nevertheless the cure was effected always by intravenous injections of plasmoquina.

Considering the universal prevalence of malaria, it was curious to note the relative scarcity of mosquitoes.[8] One would expect great hordes of them at night, yet actually they were scanty in number. Señor Castro had puzzled over the matter and finally concluded that the constant rains washed away all the larvae, and such a deduction must have a semblance of fact, because immediately after a period of several comparatively dry days it has been noted that the mosquitoes are noticeably more numerous.

Undoubtedly there are several distinct types of diseases all classed by the populace indiscriminately as "fevers."[9] There is the distinction of one, however, the intermittent fever said to be transmitted by the bedbug.

Among the children there are numerous ailments, the more common being intestinal worms and a horrible ulcerous condition known locally by the name of "*bubo.*"

Ethnologically the Chocó Negro is interesting because of his physique; all the men being magnificent, broad-shouldered specimens. Whether this pure type results as the working of the Darwinian law of the survival of the fittest, together with the superhuman labor of propelling dugouts upstream with crude paddles, or whether it harks back merely to the possibility that the original shipment of

FIG. 3. VILLAGE HOUSE
IN LLORÓ, ANCIENT SPANISH SETTLEMENT.

[8] John C. Trautwine, *Jour. Franklin Inst.*, 57–58 (3rd ser., vol. 27–28), p. 42, 1854.

[9] John C. Treadwell, *op. cit.*, p. 234.

slaves to the Chocó were all captured Negroes, can be only conjectured.

The black man of Quibdó or of the other scattered villages (Fig. 5) is far from savagery, but his brother of the river bank can be designated as only semi-civilized at best. At present, true enough, it is taken for granted that a breechclout is not the proper costume for visits to Quibdó or any other of the larger settlements; the black has come to regard clothing as a desirable thing, even though his finances permit nothing more than a ragged undershirt and a tattered felt or straw hat in addition to the loincloth. The women, too, are prone to the use of a cotton dress cut according to the latest available style catalogue. All this present preoccupation with clothing has come about partly because of the influence of the Jesuit missionaries but perhaps more so from the affluence brought on some

FIG. 4. PART OF RIVER FRONT AT QUIBDÓ, SHOWING CHARACTERISTIC DUGOUTS.

FIG. 5. RIVER MARKET AT QUIBDÓ
NOTE METHOD OF ANCHORING THE DUGOUT WITH A POLE.

years ago when platinum fetched 18 pesos for each "*castellano*" (roughly one sixth of an ounce). During this time there was great activity in the Chocó; the Negro had much money and spent freely, although his desires were limited.

The chief staple of diet is the plantain, which is consumed in a variety of fashions—roasted, fried or boiled; but the banana also is eaten in large quantities. Other fruits are used; the fleshy seed of various types of the "*chontadura*" palm, *Bactris* spp., one tasting like roasted chestnuts, another like mushrooms; the avocado; pineapple; papaya; the "*sapallo,*" a green-striped, short-necked squash; the squash-like "*badea,*" *Passiflora quadrangularis* L.; and to a lesser extent various products of tropical trees, like the "*caimito,*" *Lucuma caimito* (R. and P.) R. and S.; the "*almirajó,*"

FIG. 6. TYPICAL JUNGLE DWELLING, WITH SURROUNDING PLANTAINS.

Matisia alchornaefolia Tr. and Planch.; and several edible fleshy roots of smaller plants, like the "*yuca,*" *Manihot* spp.; the "*mafafa,*" *Colocasia esculenta* (L.) Schott.; and the "*ñame,*" a cultivated yam producing enormous roots measuring sometimes 3 feet long. From a palm, *Bactris* spp., are secured terminal buds, "*cogollo,*" which are eaten raw or boiled. The lime and orange seem to thrive as scattered trees in the villages, but the people are not prone to use the fruit except as a medicinal preparation —principally to counteract fevers. My house boy, for instance, had never heard of any one drinking raw orange or lemon juice and always insisted on boiling such preparations for me.

Sugar cane thrives as an important crop, because from it is secured the crude brown sugar, "*panela,*" a much prized food of the boatmen (see Fig. 7 for mill). Corn, too, has universal use when ground to a pulp and baked in biscuit-like cakes, called "*arepas,*" but this article of food is somewhat limited because of the difficulty in the cultivation of the crop.

The constant, heavy rains contrive to keep the soil in such a soggy condition that corn plants are not highly productive. The common practice is to broadcast the seed (see Fig. 15 for broadcasting basket) during February and March or during a shorter season in September, after the trees and brush have been chopped down. These two seasons have been settled upon by the Indians as the only periods in which corn may be planted. The land can not be cleared because the felled material never dries sufficiently to be burned.[10] The corn is called locally "*maíz indio*" (Indian corn) and is said to be the same strain

[10] G. Mollien, "Travels in the Republic of Colombia in the Years 1822 and 1823," pp. 301–308. London, 1824.

used by the aborigines long before the discovery of America. The stalks attain a height of 4 to 5 feet, bearing usually two ears—although I was told that three or four ears was a common harvest. The ears measure 4 to 6 inches long, with a diameter of about 1½ inches; the grains being predominately yellow but mixed with a few white ones.

Another food plant, though not commonly used, is the tree fern "*tasí*," *Alsophila rufa* Feé (Fig. 8). It is said that a person lost in the jungle can subsist for days on the pith, which is unusually free from fibers. It has a not disagreeable flavor, resembling somewhat that of Irish potato but with a degree of sliminess like okra.[11] The young leaves of "*col de monte*," *Phytolacca rivinoides* Kth. and Bouché are used in salads by the country folk.

[11] J. C. Piperton, Hawaiian Exp. Sta. Bul. 53, 1924.

For daily beverage the river Negro uses a black, over-parched coffee ground to a dust, or chocolate either in the bean or already extracted and prepared. But often the seed of a leguminous shrub "*potra*," *Cassia occidentalis* L., is employed as a substitute or as an adulterant to conserve the supply of coffee on hand.

Aside from food, there are numerous plants with reputed medicinal properties. At times, from the remarks of my guide or of a casual passerby, I was inclined to believe that nearly every plant had some medical application or other, but, of course, in many of these cases the efficacy of the remedy must be rather dubious; for example, the beautiful fern "*lorito*," *Trichomanes elegans* Rich., indicated by a few people as a snake-bite remedy; as was also "*chupadera*," *Draconteum costaricensis* Engl. (?). Nevertheless, many of the plants do possess unquestionable therapeutic value. For instance, my

FIG. 7. COMMON TYPE OF CANE MILL
EVEN THE MILLING OF THE ROLLERS IS HAND-CARVED.

friend, Dr. Cordoba, supplied me with specimens of plants which he uses constantly in his practice, *i.e.*, "*yerba dulce*," *Borreria latifolia* (Aubl.) Schum., as a diuretic; "*sombrerito del diablo*," *Cephaelis tomentosa* (Aubl.) Vahl., for relief of asthma and as an emmenagogue; "*yerba mora*," *Solanum nigrum americanum* (Mill.) Schulz., for diseases of the spleen and liver, also to wash wounds; "*Doña Juana*," *Adenostemma laveria* (L.) Kuntze, to wash wounds; and "*pacunja*," *Bidens pilosa* L., to reduce fevers; and "*mazamora*" *Brownea* sp., as an emmenagogue. Furthermore, I was told of the blistering effects of the bruised leaves of "*jasmincillo*," *Petiveria alliacea* L., much used as a counter-irritant and also to produce ulcers by malingerers to escape military service or by beggars to elicit more alms. The "*vitoria*," *Gurania wagneriana* Cogn., is said to be a counteractive for the ulcers produced by the poisonous liana, "*yateví*."[12] One Negro showed me the nearly healed scars which for four months had resisted all treatments until some one had suggested the use of powdered leaves of the "*vitoria*" applied as a dust. The "*amarga*," *Psychotria cooperi* Standl., is used as a decoction for the relief of rheumatism; "*chulco*," *Monolena cordifolia* Triana, and also *Begonia humilis* Ait. as a maceration for bilious attacks; while the cooked leaves of "*yerba de pollo*," *Vandellia diffusa* L., induce vomiting; the "*lombricera*," *Spigelia anthelmia* L., is thought to be a good cure for worms in children; "*mano de tigre*," *Neurolaena trilobata* (L.) R. Br., is considered by some natives as efficacious in the treatment of gonorrhea; and "*yerba de Adán*," *Chelonanthus acutangulus* (R. and P.) Gilg., is used to alleviate neuralgia; while "*yerba de sapo*," *Conobea scoparioides* (C. and S.) Benth., a plant with menthol-like flavor, cures toothaches. The large tree "*clavellín*" (a new species of *Brownea*) with blood-red flowers and reddish sap is widely accepted as a thoroughly good hemostatic. The cultivated shrub "*saúco amargo*" is used universally as a fever deterrent, as is the sterile, rank-growing grass "*limoncilla*," *Cymbopogon citratus* Stapf, which has a strong odor of lemon. The liana "*china*" with spiny leaves is said to be a remedy for sterility in barren women.

Aside from these medical plants sought in the wild as needed, each household has a garden of plants in pots of soil mixed with charcoal elevated in hanging gardens[13] to escape the soggy ground (Fig. 9); such plants as "*albaca*," *Ocimum basilicum* L., much used to produce sweats in the treatment of fevers; and the red-leaved "*sanguinaria*," *Oxalis hedysaroides* H. B. K., employed in the case of hemorrhage after childbirth. In these same gardens will be found onions and tomatoes, looked upon more commonly than not as medicinal rather than as food.

This undesirable wet character of the ground has brought to nil all attempts to produce pastures for cattle; because in the first place only a few grasses are suited to the peculiar climate, and secondly if a stand is secured it is soon killed out after the cows trample the grass into the ground to leave deep holes at each footprint. These holes soon fill with water and the hot sun raises the temperature to a point that the grass is killed. Thus the Chocó is a cowless land, and milk is to be obtained only in tins or from the few goats.

The few plants mentioned by no means

[12] Mentioned by Robert Blake White, "Economic and Medicinal Plants of Colombia, South America," p. 30. (Unpublished Ms. Photostat copy in Div. Plant Exploration and Introduction, U. S. D. A.)

[13] G. Mollien, *op. cit.*, pp. 301–303.

include all those of economic importance to the Negro, but merely the comparatively few which the author fortunately found in flower or fruit.

Others of interest are the "*canutillo,*" *Pariana lunata* Nees., the broad, stout leaves of which are utilized by the primitive miners to wrap gold or platinum dust;[14] the "*mora,*" *Leandra subseriata* (Triana) Cogn., which furnishes stems for the universal "*churembelas*" or home-made pipes of tin or clay, in which are smoked sections of crude cigars; the tall shrub "*jaboncillo,*" *Isertia pittieri* Standl., the leaves of which are used as a soap substitute and the waxen perfumed flowers as funeral wreaths; the "*heliotropo,*" *Hedychium coronarium* König., with sweet-scented flowers and cultivated in the public park at Quibdó; the "*cañagria,*" *Costus* sp., a cane-like plant used by the primitive goldsmiths for furbishing gold ornaments in the last stages of the crucible; "*milpesos,*" a palm which yields a splendid cooking oil from the seed; and most interesting of all the "*aceite*" tree,[15] which is tapped for an oil that is used in place of kerosene for illumination in the crude, tin wick-lamps.

For meat the Chocó people depend almost entirely upon the abundant fish which are caught in a variety of manners; by seine perhaps most commonly, by use of plant poisons and by traps, of which every family tends a few. These traps, fashioned from split bamboo or palm stems, seen scattered all along the river banks, are of two types. One, called "*corral,*" a box-like affair about two feet square, has a sliding door at the front, which is left open for the fish to enter. The owner visits the traps by dugout, closes the door and extracts the catch by means of a small dip net. The other type, called "*trinchera,*" is fence-like in

FIG. 8. THE TREE FERN "*TASI*" WHICH FURNISHES AN EDIBLE PITH.

that it fits across the mouth of any small stream or depression that may fill from the river. This also has a door which is closed and the imprisoned fish then dipped out with hand nets.

During the early months of the year, seining in the Atrato River is the most favored because at this time the two species of fish, "*boca chica*" and "*dentón,*" migrate upstream. The seines used are handmade, even to the nets which are knotted from a heavy twine. The handles measure about 6 feet long, the hoop about 6 feet in diameter and the net as long as 10 feet. This equipment is used in midstream from a dugout, one man holding the seine while another guides the craft. During the migration period great quantities of the fish are netted and dried to be eaten or sold during the scant season.

During migration the two kinds of fish,

[14] John C. Trautwine, *op. cit.*, p. 38.

[15] Called "incive" by Cordoba, *op. cit.*, p. 21.

FIG. 9. HANGING GARDENS
a. TYPE COMMON TO ALL NEGRO HOMES.
b. INDIAN, UTILIZING AN OLD DUGOUT.

especially the "*dentón,*" make a roaring noise so loud that two people in opposite ends of a dugout can not converse together; although there are some days when the noise subsides considerably. Nevertheless, it is the roaring that gives a clue to the fishermen to rush out with their nets because then they are certain to make a big haul. The local Negroes designate the weird sound of the fish by the Spanish word "*roncar*" (to snore), and I once heard a woman inquire of two fishermen returning empty-handed, "What's the matter, weren't they snoring?"

Unfortunately no proper preservative was at hand to bring back specimens for the identification of these unusual fish. A fish, the "*armado,*" mentioned by Darwin[16] in the Uruguay River of Argentina, which emits a harsh grating sound heard distinctly even from beneath the water, is probably not the "*dentón*" species. Likewise the "*boom boom*" catfish of Beebe[17] is probably different. Quibdó people insist that the phenomenon is not encountered outside of the Atrato River.

Other interesting examples of the fauna are the large "*verrugosa*" snakes which coil up in the crotches of trees and which make a loud barking noise in the evening; the large ant "*conga,*" *Paraponera clavata* Fabr., which produces a barely audible, shrill squeak when annoyed or disturbed; the "*brea*" bees, *Trigona suffragata* Ckll., which inhabit hollow trees and store immense quantities of honey and resin. The natives rob the hives and utilize the resin to waterproof their dugouts and in the manufacture of primitive torches, called "*ambil.*"

INDIANS OF THE CHOCÓ

The scant information relating to the indigenous people of the Chocó region exists in the scarcely available publications of Gutiérrez,[18] Cordoba[19] and Alvarez.[20]

[16] Charles Robert Darwin, "Journal of Researches into Natural History and Geology during the Voyage of H. M. S. *Beagle* round the World," p. 98. (5th ed.) London, 1889.

[17] Charles William Beebe, "Edge of the Jungle," pp. 252–255. New York, 1921.

[18] Francisco Gutiérrez, "Informe de la prefectura apostólica del Chocó durante la administratión de los misioneros hijos del innaculado corazón de María," p. 24. Quibdó, 1929.

[19] *Op. cit.*, pp. 13–18.

[20] *Op. cit.*, pp. 16, 20, 127–130.

The four distinct groups derivative from the Carib race are distributed as follows: The Cuna along the Gulf of Darien; the Noanamá in the valley of San Juan; the Citará in the upper regions of the Atrato area (Fig. 12); the Chocó (or Baudó) in the valley of the Baudó and along the Pacific coast.

Of prehistoric days there is still less known, although Gutiérrez[21] lists a number of articles found in graves in the region of Tadó. The present author saw a pair of beautiful gold filigree ear rings which had been discovered near Quibdó in an old grave by an itinerant miner. The same man told of other articles, including gold breast plates, which he had found in excavations. The local Negroes and other inhabitants know the location of various graves, but there is a decided repugnance against opening them and tales are told of the reputed dangers of violating such places. Supposedly the ancient Indians contrived many deadly traps of weighted stones to crash down upon the grave robber, or even they arranged bowls of deadly gases or poisons.

Among the Indians themselves there are, of course, legends of various sorts handed down verbally from generation to generation, but so far as known there are no published records existing.

When Cordoba[22] published his booklet for school use, the authorities would not permit the inclusion of a legend of the genesis of the Cuna Indians. Most graciously he has given permission to translate and to publish here the account secured first hand from one of the chiefs. The story follows.

Origin of the Cunas

Since we have not been able to secure a direct translation we will give a brief sketch of the origin of the tribes of the Darien according to the "*catio*" legend.

In the theogony of the "*catios*" there appears first a single god, eternal and uncreated, who is called Tatzitzetze, which means creator or father of all that exists. From the saliva of this god was formed Caragabí, overseer of the world who became learned in a short time.

Tatzitzetze was generous to a fault, which character profoundly displeased his son; so much so that he rose up against his father and defeating him was left as the universal arbiter.

Coming to the moment of creation, Caragabí produced from nothing a drop of water, which thrown to the earth and covered with a calabash, gave life to a male "*catio.*" Not content with this work, the god threw down another drop of water from which issued a woman. To her, Caragabí gave the faculty to create drops of water, but she abused the privilege and produced drops in such profusion that it rained, thus giving origin to an infinity of Cuna Indians.

These people turned out to be intelligent and active, because they learned perfectly the use of the bow and arrow and the construction of large splendid houses. But eight days after having appeared on the earth they disavowed the authority of their god, Caragabí, and wished to kill him with arrows, but were frustrated in their intent thanks to the immortality of this sovereign. Caragabí in punishment for so great an ingratitude banished the Cunas to the river banks of the Atrato.

This conduct of the Cunas, aside from their

FIG. 10. CIRCULAR "TAMBU" PECULIAR TO THE INDIANS NEAR QUIBDÓ.

[21] *Op. cit.*, pp. 124–126.
[22] *Op. cit.*

FIG. 12. TWO INDIAN MEN AND A BOY IN USUAL COSTUME, NEAR QUIBDÓ.

expulsion, gave rise, according to the legend, to continuous wars carried on between all the tribes of the Chocó.

Caragabí created for the third time a drop of water from which sprang forth Séver, and to him he taught in all perfection the use of arrows, also to rub his body with pulverized eyes of the tiger to give agility to his limbs, and to dust himself with pulverized eyes of the cavy "*guagua*" of the deer, and of the lion to increase the potency of his vision not only by day but also by night.

Séver wanted to spy on the Cunas a certain night and so he made his way toward their town, first having made a good supply of arrows which he left hidden in the sacred tree. The Cunas, upon noticing his presence, gave vigorous attack obliging him to retreat. He was followed by twenty men who expected to overtake him by following the course of the river, but Séver arriving at Genené (the sacred tree), took his arrows and with these made good account cowardly murder of their father, made vows to his dwelling in the headwaters of the Atrato.

This event awoke in Séver a mortal hate toward the Cunas, and for the space of a month he dedicated himself to the manufacture of bows and arrows. When he considered himself sufficiently armed for a new adventure against his opponents, he fell unexpectedly upon one of their dwellings and exterminated the inhabitants; without waiting for a counter attack he retired to his domain.

He then constructed a canoe according to the rules given him by Caragabí. Embarking in this with his five sons he followed the waters down the course of the Atrato, and attacked for the third time the Cunas, obtaining without great effort a victory. A month later Séver returned again, but on this occasion the Cunas resolved to make a sally. The fight took place in mid-river, and in spite of the superior number of the enemy, who maneuvered twenty canoes crowded with combatants, Séver and his five sons drove them back. In the following trip, Séver appointed his third son, Chiamo, as spy but he was surprised in a cane patch and killed by the Cunas. The father in reprisal set fire to the cane patch, thus driving from their hiding place the Cunas, and gave battle to them on a beach. There after having subdued them, he tore out the teeth of the dead and of the prisoners. These trophies he made into a string which he hung in his habitation. They became objects of superstition to the extent that they rang like bells to announce any new triumph of Séver over his enemies.

The Cunas in their turn sought revenge but with such ill luck that in a new encounter no one was left to relate the adventure. In return, those who had escaped the battle made prisoner the youngest son of Séver and carried him away as hostage. The father attacked them, setting fire to fifteen dwelling places. In the retreat of the Cunas, Emágai, son of Séver, challenged the enemy chief to single combat and emerging victor gave occasion for the chief to flee.

Since the courageous ones were not subdued by this incident, Séver returned anew against his opponents and conquering them retired afterward to his possessions satisfied with the triumph. But a few days later, while bathing in the river, he was surprised by an advance guard of the Cunas and killed. From one of the bones of the hero, the Cunas fashioned a flute but it always came apart in the middle at any attempt to play it. The sons of the leader, aware of the cowardly murder of their father, made vows to avenge it. They fell unexpectedly upon the tribe, wrought terrible punishment and then took possession of their lands.

According to Cordoba[23] the Indians are suffering gradual extinction and of the former flourishing tribes there remain but a few scattered settlements and of these only two have a semblance of organization with a "*cacique*" or chief, but there still exist a number of "*jais*" or medicine men. The "*jai*" practices a

[23] *Op. cit.*, p. 13.

sort of witchcraft and preserves secret preparations of herbs.

For many years the missionary priests have worked to convert the Indians to the Catholic religion, and in the main their success has been good, although the "*jai*" still retains considerable influence, especially in cases of illness when there must be conferences with the evil spirit or devil, who if properly approached will tell the "*jai*" which herbs must be used for remedies, or he may pronounce the case incurable.

The "*jai*" lives in a hut indistinguishable from the others in the community and his official equipment is simple, consisting usually of a carved staff and a stool, both sacred. On occasion he comes to the afflicted household, and sitting on his stool, thumps the staff in time with his chanting which may last all night if necessary to attract the devil into conversation. If the patient is important many devils of various localities may be called in, but ordinarily only the local spirit is needed.

In preparation for the incantation three young girls are chosen to prepare the special "*chicha*" or fermented drink. They are shut up in a reserved place with a quantity of the ground corn, and if any one should unwittingly spy upon them the "chicha" is thereby profaned and would need to be prepared anew. When all is ready the special beverage is placed about on the floor near the "*jai*," in order that the devil may partake; the family of the patient become drunken from their own supply of the liquid, and the "*jai*" starts his weird chant.

If by chance the Indians should lose confidence in their "*jai*" they send word to the police of Quibdó to take action. This results usually in the departure of a deputy to visit the settlement, and if necessary to deprive the erring one of all his religious accoutrements. Thus disgraced he can no longer practice his magic and is forced to resign in favor of a son or near relative.

Sr. Cordoba once acted as such a deputy and at that time deprived the "*jai*" of a staff; a stool; various calabash shells and large wooden "chicha" bowls; wall ornaments of crossed pieces of wood cov-

FIG. 11. ALONG THE TUTUNENDO RIVER

A VIRGIN AREA, WHERE MANY OF THE BOTANICAL COLLECTIONS WERE MADE. NOTE THE EXTREME CLARITY OF THE WATER.

FIG. 13. MODE OF TRAVEL IN THE CHOCÓ

ered with engraved designs; many sorts of green branches and fresh flowers used in the preparation of decoctions; and a miniature witchcraft boat of balsa wood (Fig. 14), patterned after the shape of the river steamer that visits Quibdó. This last article, now badly dismantled, had originally a wooden roof, a steering wheel and some twenty warriors variously painted, the chief armed with a saber, the rest with rifles. The "*jai*" said that he had purchased the boat from one of his brethren practitioners at a price of about twenty pesos.

Among the "*jais*" there exist great rivalry and constant witchcraft warfare. The miniature boat just described was used in such assaults; but more often one contestant may take the form of an animal, usually that of a pig, to do battle with another.

Each Citará family is a complete, self-sustaining unit, manufacturing its own utensils and implements, although in one place I learned that a neighboring artisan produced all the blowguns for the community and that another specialized in the preparation of the poisons for the blowgun darts.

The women weave many types of baskets (Fig. 15), attend to all the household duties and care for the cultivated crops; while the men build the houses, clear the land and hunt.

The men usually speak Spanish, but the women as a rule will not or can not converse in any but their native idiom. The numerical system of the Citará Indian does not extend beyond ten, and the head of one household remarked that for this reason the women could not be entrusted with commercial transactions. When asked how a woman could know when she had more than ten children, he merely shrugged his shoulders and replied that regardless she was unable to count over ten.

Phonetically, and according to the Spanish sound values, the numerical system might be represented as follows: one, *abá;* two, *umé;* three, *umpea;* four, *quimáre;* five, *uesomá;* six, *uaquirar-ambá;* seven, *uaquirara-umé;* eight, *uaquirara-umpéa;* nine, *uaquirara-quimáre;* ten, *jiquaiguará.*[24]

[24] A. L. Pinart, "Vocabulario Castellano-Chocoe (Baudo-Citarae)," Paris, 1897; Frederick Collins, *op. cit.*, pp. 118–119.

The Indian is becoming more and more dependent upon cultivated crops and domesticated animals for his food, where formerly he lived by the hunt and chase alone. Many days the family has no meat because the hunter has returned empty-handed after a long hunt, and at times like this they simply eat more rice or boiled plantains. The parrots are now wary and fly too high to be shot; the monkeys no longer frequent the haunts of man. It is a hard struggle indeed to wrest a living in competition with the increasing Negro population.

About one Indian house I noted in cultivation bananas; plantains; a species of short palm, bearing basal bunches of red fruits; corn; and "*cañabrava*," *Gynerium* sp. In a hanging garden (Fig. 9, *b*) made of an old canoe there were several of the medicinal "*albaca*," *Ocinum basilicum* L. Oftentimes are cultivated other plants, such as those for perfume, *i.e.*, "*bejucillo*," *Vanilla fragrans* (Salisb.) Ames and the thick-leaved "*manduro*" (not identified); the fish poisons "*chirrinchao*," *Phyllanthus acuminatus* Vahl., "*catalina*," *Clibadium polygynum* Blake, and "*varbasco de castilla*," *Tephrosia toxicaria* (Sw.) Pers.; and the basket dyes "*umbisca roja*" (perhaps *Arrabidea* sp.) and "*umbisca negra*" (not identified).

Commonly though the Indian depends upon chance finding of a desired plant in the surrounding forest and during the time of the expedition under discussion it was possible to note but a very few of such plants, *i.e.*, the dwarf "*nolí*" palm, *Tessmanniophoenix dianeura* Burret, which produces a kind of cotton from the leaf bases; the "*pita*," *Ananas magdalenae* (André) Standl., which furnishes a long stout fiber; and the "*fruto de pavo*" (not identified) with edible yellow fruits. The large fruits of the "*jagua*," *Genipa americana* L., are ground to a pulp and the juice anointed on the body to produce the deep blue-black, indelible stain which the Indians believe to prevent sunburn; fiber cloth of large dimensions, employed as sleeping pallets or blankets, is obtained from the cortex of the huge tree "*damagua*," *Pachira alba* L.[25] Most interesting of all is the clambering shrub variously called "*querá*," "*quedá*," "*querie*," and derived from the native name "*quidai*," meaning tooth.[26] This

[25] *Op. cit.*, p. 9.
[26] *Op. cit.*, p. 119.

FIG. 14. WITCHCRAFT BOAT OF INDIAN "*JAI*"
(ABOUT TWO FEET LONG).

plant has been identified by Paul C. Standley, of the Field Museum, as a new species of the genus *Schradera*. The Indians of the locality all chew the plant at intervals of about six months in order to blacken and supposedly to preserve their teeth.[27] The "*tahiti*" plantain is interesting in that the fruit sheaths are reputedly the source of a deadly poison for the blowgun darts.

To learn the numerous plants employed in one way or another would require much time and patience to overcome the distrust of the Indian. But probably the effort would be worthy of attempt in order to authenticate the numerous tales of secret preparations employed; for instance, there are many people who believe the Indian still knows the plant supposedly used in ancient times to produce malleable gold; secret remedies are numerous for snake bites, and some of the medicine men offer to sell such for an agreed price; there is a cure for baldness; one for toothache; and so on endlessly.

Generally speaking, the flora of the Chocó, though profuse in species, is most scanty in flowers or fruits. There seems to be no definite period of inflorescence and from my own observation and that of several local men it would appear that a large percentage of the jungle plants never produce seed but instead reproduce vegetatively, due probably to the constantly humid climate. Possibly to spend a longer time in the area might disclose more preponderance of the sexual mode or reproduction.

It was something of a disappointment to labor long hours under trying climatic conditions to be rewarded with only a comparatively few specimens. For example, in the two months spent by the author in the Chocó, only 560 specimen numbers were obtained, although observations were made and the common names secured of a considerable number of economic plants that were sterile at the time.

Future explorers in the Chocó have in store many interesting discoveries in all branches of scientific interest. The few specimens of economic plants collected by the author represent but an insignificant part of the great number that exist there. If properly approached, the Indians and Negroes would certainly reveal many of their secret remedies. A man of sufficient fortitude to resist the hardships of the climate and with a small financial outlay could within a year or two secure much valuable data and numerous specimens; material which would probably result in economic benefits to the country, to say nothing of the purely scientific results that would accrue.

The main object of the two-month expedition was the collection of plants in a country botanically unexplored. Although many of the Triana and Planchon[28] collections are cited from Chocó, yet it would appear that none was secured from within the present limits of the territory, until recently included in the Department of Cauca. Trautwine[29] was accompanied by a physician, Dr. Mina B. Halsted, who collected plants along the Atrato River, but no trace has been found of his specimens nor of a report of the data.

Aside from the botanical aspect there are scanty publications that deal with other phases of the country; Mollien[30] gives a few general observations and says that the country is scarcely known; this last statement was repeated a hun-

[27] W. Andrew Archer, *Jour. Wash. Acad. Sci.*, 24, 1934.

[28] José Triana and J. E. Planchon, "Prodomus Florae Novogranatensis," Paris, 1862.

[29] *Op. cit.*, pp. 1–2, 18.

[30] *Op. cit.*

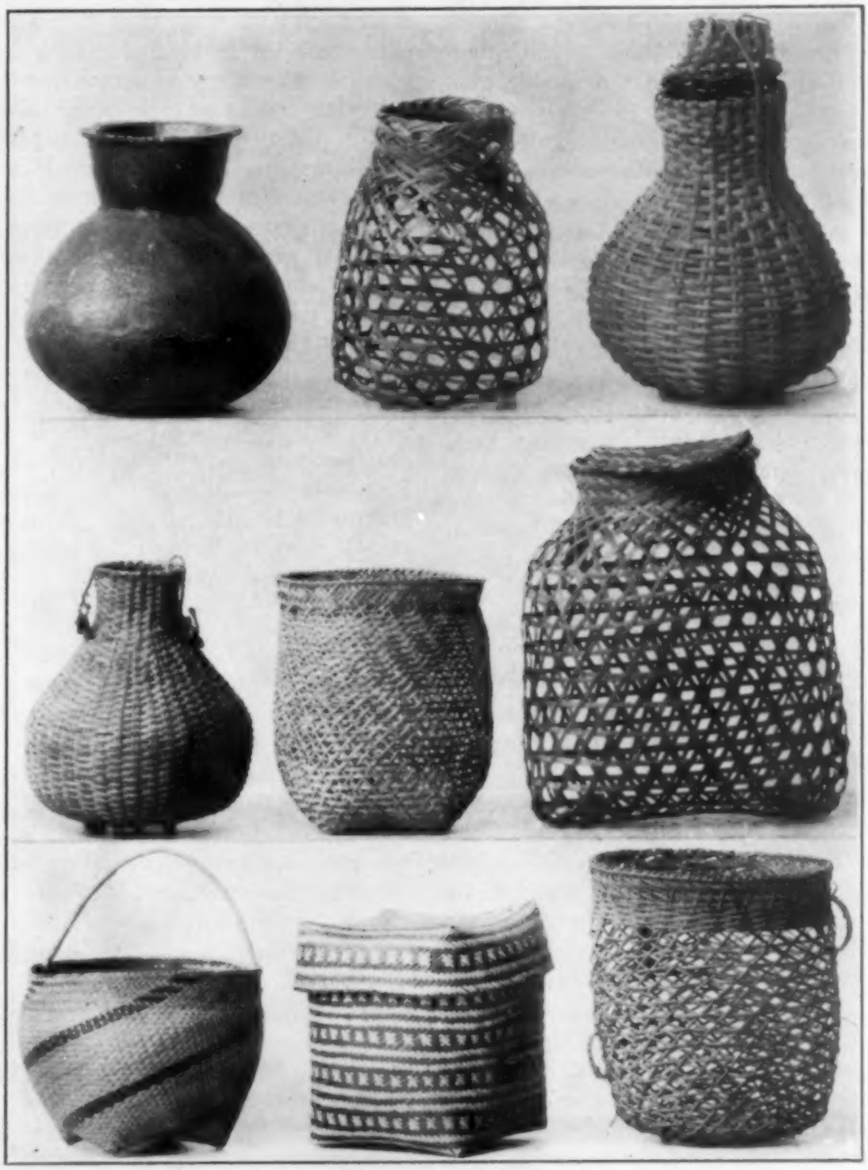


FIG. 15. INDIAN HANDICRAFT

Top Row: left, CHICHA JUG; *center,* BIRD CAGE FOR CHILDREN; *right,* BAIT BASKET FOR LIVE GRASSHOPPERS. *Middle Row: left,* CORN BROADCASTING BASKET; *center,* GENERAL UTILITY; *right,* USED TO CARRY LIVE GAME AND CHICKENS IN DUGOUTS. *Bottom Row: left and center,* NEGRO BASKETS COPIED FROM INDIAN DESIGNS; *right,* INDIAN CORN HARVEST BASKET.

dred years later by Edor,[31] Hyatt[32] and Treadwell.[33] A few other publications, Cordoba, Alvarez and Gutiérrez, though containing intimate details, are in Spanish and furthermore not available generally in libraries. In 1930, Dr. Carlos Ermisch, of Berlin, traveled rather extensively in more remote sections of the country, and undoubtedly his geological data will be published. Mrs. Elizabeth Lee Kerr, now in Cartagena, is writing her biography of long years in the Chocó jungles as a lone collector of bird skins for various museums of the United States.

Naturally the present article can not be considered as anything more than a scant statement of a few incomplete observations which the author wishes to record with the hope that later a proper expedition might be undertaken for the purpose of securing adequate records and materials from this interesting area.

For the intimate friendship bestowed by Sénor Don Rudolfo Castro B. and by Dr. Don Francisco Cordoba M. the author expresses deep appreciation. Without the cooperation of these two leading men of Quibdó it would not have been possible to have secured the more valuable data and specimens. Much credit is due to many other people of Colombia who assisted in various capacities; and to different members of the Smithsonian Institution, especially Mr. Ellsworth P. Killip and Mr. William R. Maxon for identification of plants and to Dr. Herbert W. Krieger for photographs of ethnological collections.

31 Phanor J. Edor, "Colombia," London, 1919.

32 A. Hyatt, "Panama, Past and Present," 1921.

33 *Op. cit.*, p. 214.

HEALTH HAZARDS OF CHEMO-ENEMIES IN CONTAMINATED FOODS

By Dr. P. J. HANZLIK

PROFESSOR OF PHARMACOLOGY, STANFORD UNIVERSITY SCHOOL OF MEDICINE, SAN FRANCISCO; CONSULTANT IN PHARMACOLOGY, SAN FRANCISCO DEPARTMENT OF PUBLIC HEALTH, AND U. S. DEPARTMENT OF AGRICULTURE

It has been aptly said that the vitamins, those invisible accessories of our diets, are the little things of nutrition. Equally so, it may be said, the heavy metals, such as mercury and arsenic, are the little things of therapeutics, the art and science of treating disease. These metals are, in many respects also, the tiniest things of toxicosis, the state of protracted ill health. Indeed, they may be the most insidious underminers—chemo-enemies—of normal cellular and tissue activity. This seems paradoxical, for apparently, on the one hand, these metals may be beneficial to health, but on the other, they may be detrimental. In other words, they can blow both hot and cold. To the uninitiated this paradox seems a surprising state of affairs. Not so to the medical scientist, who knows that the vitamins and hormones, which also exist in traces and are necessary for health, may, when abused, produce chronic illness or serious disease. Nevertheless, it is right here that much confusion exists. Laymen, and many scientists too, are apt to think only of the sudden outbursts of symptoms of poisoning as the only manifestations of dangerous effects. Dramatic, if not violent, effects do occur from the use or swallowing of large doses of the heavy metals. These, however, are not concerned in the slowly developing and continuing effects of tiny quantities to which vast populations are exposed, day in and day out, under the modern conditions of our existence.

Of particularly great concern are those heavy metals used to combat the insect pests which exist in myriads and would deprive us of the foods for our very existence. The commonest of these metals in use are lead and arsenic. We can obtain the food abundantly and economically with the aid of lead and arsenic, but these same metals may defeat the joy and the purpose of consuming that food. If we do not use the lead and arsenic, we may not have the food. If we are to have the food, we may have to take some lead and arsenic with it. It would seem a problem of relative values—some good at the expense of some harm. What we desire to know is whether our health is really in danger, if we eat such contaminated food. Many expert scientists, who have investigated the possibility, think it is. Some few people, not experts, have claimed these things to be trivial. Therefore, what experts think may prove enlightening and useful, particularly about lead, which in many respects is more important in this connection than is the arsenic.

Although lead arsenate is actually the spray residue that concerns fruit and vegetable growers and public health authorities, it is the lead which will bear emphasis, because this metal has long been recognized as an insidious menace to the health of the people. Lead has generally been regarded as a cumulative poison, a fact which has been repeatedly corroborated by the most rigid investigations. Time and again, it has been shown that lead accumulates in the viscera and bones from which it is gradually and continuously released according to conditions in the body. It is this continued streaming of lead through the body, whether the metal comes from storage-

depots within the body or from channels of absorption, that causes cumulative injuries to important bodily functions. These injuries result in manifestations of impaired health which are not generally recognized by the layman as originating with the eating of contaminated food. Growers generally do not appreciate the dangers of chronic cumulative poisoning, which is quite a different thing from acute or sudden poisoning. Chronic poisoning is really a disease and not a poisoning in the ordinary sense.

The disturbances in the beginning resemble those from some common disorders. Most practicing physicians now recognize that many people, residing in localities where insecticidal sprays are used, show symptoms which can be ascribed to lead or arsenic or both. These symptoms are characterized by loss of appetite, malaise, loss of body weight, weakness, fatigue on exertion, anemia, constipation or other gastrointestinal disturbances, and later pains in joints and nerve paralysis. Lowering of resistance to infections and predisposition to disease are also believed to occur. In the absence of other known causes, such symptoms always should arouse suspicion of injuries from lead. These symptoms are known to be more common, or are more aggravated, during spraying seasons. Conclusive evidence of toxicity can be obtained from analysis of excreta for lead and from examination of the blood, but a diagnosis of suspected poisoning can also be made without evidence of lead in the excreta. A correlation of all evidences with a history of exposure to lead generally enables a physician to arrive at a correct diagnosis.

On occasion, I have had the opportunity of making estimates of probable amounts of contaminated fruit or vegetables which might be regarded as being detrimental to health. These estimates are based on the results of experimentation with animals and on reported intoxications in man. They can only be approximate, since considerable individual variations exist, and actual conditions in the alimentary canal determine the rate and degree of absorption of the poison. Since it is believed that only one one-thousandth of a grain, or a barely visible pinch, of lead, swallowed daily for some weeks or months, may produce manifestations of illness, it was estimated in one case that from seven and one-half grains, a quantity equal to about one and a half aspirin tablets, to two teaspoonfuls, of a certain apple pomace, a dried product from apples, eaten daily by an adult for several weeks or months would be deleterious to health. For the actions of arsenic, about four teaspoonfuls of the contaminated pomace would have to be consumed, since it is believed that somewhat more arsenic than lead is required, or about five thousandths of a grain daily, for chronic intoxication. This contaminated pomace was to be used in a variety of ways; in households, for preparing jellies, vinegar and cider, and in husbandry, for feeding live stock. In another case, it was estimated that, for the effects of lead, one whole contaminated apple eaten daily for weeks or months would be hazardous to health; for effects of arsenic, three or four apples daily. In still another case, about four teaspoonsful of a contaminated cauliflower, when eaten regularly, was estimated as being capable of producing signs of ill health. Very recently I had the opportunity of considering the potential health hazards of cabbage contaminated with lead arsenate, seized in a public market in the Southwest. Analysis showed an arsenic content of 0.02 to 0.45 grain, and a lead content of 0.09 to 1.24 grain, per pound of cabbage. Since one to two grains of arsenic may be toxic or fatal to an adult, one pound of this cabbage contained one fourth to one half a toxic or fatal dose. Frequently large quantities of cabbage are used in preparations of soups, cold-

slaw, extractives and the like, which may exercise unusual solvent actions on metals due to use of heat and presence of acids, salts and proteins. Rather large portions of such culinary products may be consumed. For instance, an ordinary portion of cold-slaw eaten by an adult is said to be about four ounces, and if it were prepared from this contaminated cabbage, an adult would eat at the same time something like one sixteenth to one sixth the killing dose of arsenic, let alone a not inconsiderable amount of lead. I did not hesitate to declare this cabbage unfit for human consumption and a real menace to health, capable of producing acute poisoning. Of course, when the lead and arsenic act together, the effects are additive, and the amount of contaminated food producing illness is less than if either metal were present alone. The effects of these poisons would be even more pronounced in children than in adults, because they may consume more poison or more contaminated food in proportion to body weight.

It should be remembered that, although sprayed apples and vegetables are carefully washed by special methods, before marketing, there is a certain unremovable residue of lead arsenate which remains on the skin, around the stem and in fractures and inaccessible parts. Careless washing, or no washing at all, may leave very dangerous residues of these poisons. It is interesting to note that hydrochloric acid is used in the washing process to remove the excess of lead arsenate from apples. This same acid is a natural constituent of the digestive juice of the stomach where the unremoved lead arsenate, the so-called tolerance limit, is dissolved and made absorbable from the alimentary canal. So the water-insolubility of the lead arsenate is not a guarantee against its toxic effects in the body. It has been argued that apples are commonly wiped or peeled before eating and the stems are not consumed. However, careless wiping does not remove the poisons, and children are likely to be forgetful or inefficient. In fact, many are known to eat a whole apple, including stem and all the rest. Moreover, several such apples may be eaten daily, and result in acute poisoning. Again, the uneaten raw portions are used up in preparing vinegar, cider and the like, or are thrown to pigs, chickens or cattle. The solubility, and hence absorbability, of the poison is promoted under these conditions of fermentative acids and other products and by digestive juices in animals.

The toxic effects of lead are also manifested in domestic animals living on contaminated feeds, pastures and water supplies. This means that the sources of food supplies for people may be contaminated where spraying is done carelessly. Economic losses in live stock have been so large in sprayed regions as to cause growers to give up business. Interesting experiences are frequently related by growers which testify to the actual menace to the domestic animals in these regions. Turkeys allowed to run in sprayed apple orchards are known to have developed lead poisoning. Horses nibbling on alfalfa or other vegetation grown between the sprayed trees are reported to have died in three or four years. Drift carried to pastures during aeroplane-spraying of adjoining ranches has resulted in repeated payments of indemnities for poisoned live stock. A valley in the Pacific Northwest has received as much as 7,000,000 pounds annually of lead arsenate, and this has been going on for about twenty years. Possibly, in the neighborhood of 50,000 tons of lead arsenate have permanently contaminated the soil of this valley. But the local population assumes the poison is washed away with the rains, or blown away by the winds which generously sweep these regions. Nothing is farther from the truth. The soil retains permanently by

adsorption most of the poison strewn upon it, the poison only to be gradually released and taken up by the vegetation growing on such soil. It has been argued that rodents live contentedly in the contaminated soil, and keep on multiplying and menacing the industry even more than spray residues. Some say the bodies of these animals, and even of the people, may contain traces of lead and arsenic, and what of it, if they do.

Although lead may be found in traces in body fluids and tissues of many people, owing to the general use of sprays, ethyl gasoline and contaminated food products, this is not an argument for its harmlessness or its naturalness to the body. On the contrary, medical authorities now believe that such a general presence of lead in the population is a contributory factor to, if not a direct cause of, some common disorders whose etiology has hitherto remained obscure. Among the latter are included even such diseases as cancer, arteriosclerosis and nephritis, although there is a considerable division of opinion here. Moreover, lead never was intended by nature to be a constant or "natural" element of the body; neither arsenic, for that matter. Lead is no longer prescribed or used internally as a medicinal agent by qualified physicians; arsenic may be used, but only under supervision of a qualified physician. Colloidal lead, which has been tried in cancer, is an experimental proposition far from being generally accepted. It is misleading and improper to speak of "normal lead," as it is never present in the body in the absence of exposure, and serves no useful purpose when it is present. Certain sources of diet may not be entirely free from lead (also arsenic), but that is no justification for condoning or allowing its presence. Obviously, therefore, exposure to lead in any form or by any channel, which will cause its appearance in the body, can not be regarded other than as a hazard to health.

Investigations, which disregard established facts or fail to recognize accepted principles and procedures commonly employed in modern studies of chronic intoxications, are likely to result in premature conclusions or deceptive announcements. Just recently some commercially inspired studies, which are reported to have pooh-poohed the lead arsenate of spray residues as a health hazard, are likely to create misleading impressions and a false sense of security. Unless and until such reports are submitted to experts capable of assessing their true value, they must be regarded as being at complete variance with disinterested researches conducted by scientists the world over. The promotion of commercial enterprise with the aid of insidious poisons, such as lead, is unwarranted when done without control or discrimination and with an utter disregard of the effects of such practice on man. The burden of proof rests with those who would maintain or encourage the contrary without warning or protection of the public.

What is to be done? It would help all concerned, the growers, the enforcement authorities and the people generally, if some independent or government agency would undertake a complete "epidemiologic-toxicologic" survey of a region which has been well sprayed for years. This would get at all the facts concerning soil, animals, people, vegetation, industrial regulation, desirability of tolerance limits for the poisons and other related matters of interest. This would help the government enforcement agencies in carrying out the will of the people. The United States Department of Agriculture has already done a great deal to make the public conscious of, and protect it against, this menace, but there are apparently also limitations to its

power and influence. It is evident from the results of recent prosecutions of many violations that the public is not yet awake to the real situation. The merits of the problem are often obscured, or smoke-screened, by irrelevant matters and trivialities. Government control is interpreted as persecution of, or interference with, legitimate business. The truth is that the federal authorities are actually concerned with the economic aspects, as well as with health hazards. In fact, they are the only ones doing anything constructive about the situation. A great deal of research is being done under federal guidance to determine the best possible insecticides whose health hazard would be negligible and the costs minimal. The proper way to deal with the health hazard of heavy metals, like lead, is to eliminate their use altogether and to develop new insecticides of a totally different kind. This is actually being done experimentally, and it is not too much to hope that practical success will soon be achieved.

In the meantime, producers should avoid the use of lead arsenate or other arsenicals on vegetables like cabbage, cauliflower, Brussels sprouts, broccoli, spinach, kale, celery and snap beans, which are consumed in their entirety. They should use the most effective means possible for removing spray residue from the surface of apples and other deciduous fruits; and they should not use the skins of sprayed fruits in the production of cider, vinegar, jelly, stockfeed or other food products. Consumers should be careful to wash as thoroughly as possible all vegetables and deciduous fruits that might have been exposed to spraying. Apples that are to be eaten with the skins on should be scrubbed with a wet brush, rinsed and have the skin removed around the stem and blossom end. The parings or skins of commercially grown fruits and the pods, husks or tops of commercially grown vegetables should not be fed to poultry or live stock.

Nothing has been said here about other insecticides which have been tried, such as nicotine, selenium and fluorine. All these have proved unsatisfactory, for one reason or another. Either they are inefficient or impractical as insecticides or they are equally or more dangerous to health. The ravages of children's teeth in fluorine-infested regions of the Southwest and the monstrosities among domestic animals in the selenium-infested regions of the North should serve as sufficient warnings to the people of hitherto unsuspected or neglected hazards. These disasters should be ample reminders of the insidious menace of the metallo-poisons to people everywhere. Of immediate concern, of course, are lead and arsenic, with a greater emphasis on lead, because these are the metals which are used deliberately, though permissively within limits, in such enormous quantities. These provide a large scale exposure of thousands of people and animals and are concealed in and contaminate their articles of diet, without their knowledge or consent. Administrative regulations, which permit so-called tolerance limits of these poisons on foods, are undoubtedly applied with good intentions, and are legally essential for effective public protection under the present terms of the law. However, they are purely arbitrary and do not meet objections raised by scientists. To the latter, the health hazards of these tiny chemo-enemies are real and important. It seems clear that only those chemical substances, which are relatively non-injurious to human health and thoroughly established by scientific research on animals and men, should be used to satisfy the increasing demands for efficient insecticides.

FRANCIS AND ROGER BACON AND MODERN SCIENCE

By Dr. FERNANDO SANFORD

EMERITUS PROFESSOR OF PHYSICS, STANFORD UNIVERSITY

In my college days I became greatly impressed—as who of those days did not?—by the far-famed learning and wisdom of Francis Bacon. I read "Bacon's Essays," but none of his other works was at hand. In the "History of English Literature" which we used as a text book in my freshman year, we were told:

> Two centuries and a half of Bacon's theory in practice have revolutionized the literary, the commercial, the political, the religious, the scientific world.

We were told that Bacon's mission "was not to teach the results of investigation, but to show the method by which investigation should be made." We were told of the philosophy which Bacon undertook to supplant:

> It was a compound of the freaks of speculation. It had nothing in common with the practical science of modern times. It was the old Aristotelian philosophy robbed of its slight veneration for nature and perverted by many unwarranted interpretations. We call it scholasticism. No one of its devotees was bold enough to step from the platform of authority.

I had no means of knowing how radically false were all these statements. We were given the eulogy of Bacon by Edmund Burke:

> Who is there that upon hearing the name of Lord Bacon does not instantly recognize everything of genius the most profound, everything of literature the most extensive, everything of discovery the most penetrating, everything of observation of human life the most distinguished and refined?

Of course, we also had Pope's famous line: "The wisest, brightest, meanest of mankind."

Later, we read "Macaulay's Essays" "to improve our style," and I found that to whatever other eulogists had failed to say of Bacon's influence upon scientific thought Macaulay added. Thus he says of the "Novum Organum":

> No book ever made such a revolution in the mode of thinking, overthrew so many prejudices, introduced so many new opinions.

Again:

> the glance with which he surveyed the intellectual universe resembled that with which the archangel, from the golden threshold of heaven, darted down into the new creation.

I can not forbear giving three more sentences from Macaulay which give us a poetical picture of Bacon's outlook on the world of his day. After telling that Cowley in one of his poems compared Bacon to Moses standing on Mount Pisgah, Macaulay says:

> It is to Bacon, we think, as he appears in the first book of the Novum Organum, that the comparison applies with peculiar felicity. There we see the great Lawgiver looking round from his lonely elevation on an infinite expanse; behind him a wilderness of dreary sands and bitter waters in which successive generations have sojourned, always moving, yet never advancing, reaping no harvest and building no abiding city; before him a goodly land, a land of promise, a land flowing with milk and honey. While the multitude below saw only the flat sterile desert in which they had so long wandered, bounded on every side by a near horizon, or diversified only by some deceitful mirage, he was gazing from a far higher stand, on a far lovelier country—following with his eye the long course of fertilizing rivers, through ample pastures, and under the bridges of great capitals—measuring the distances of marts and havens, and portioning out all those wealthy regions from Dan to Beersheba.

When I first read Macaulay I had not learned from Lowell that "poetry is not

made from the understanding"; nevertheless, I was not sufficiently carried away by emotion to accept the evidences presented by Delia Bacon and her disciples that Francis Bacon had written the plays and poems of William Shakespeare.

It was after I had been teaching science for some twenty-five years that I first read Bacon's "Advancement of Learning" and "Novum Organum," and I was much disappointed in my expectation of their importance. Some ten years later I read both books again, and was more than ever puzzled at the reputation which Bacon had derived from them. Now, after twenty more years, when my time, and perhaps my judgment, have come to be considered of little value, I have undertaken to inquire into the condition of scientific knowledge and practice in Bacon's day, and to find what changes in ideas or in methods of research have occurred as a result of the "Novum Organum."

This is not easy to do. Bacon tells us ("Novum Organum," p. 332):

> The sciences which we possess have been principally derived from the Greeks, for the additions of the Roman, Arabic or more modern writers, are but few and of small importance, and such as they are, are founded on the basis of Greek inventions.

This is perhaps true regarding the Romans until their great scientific awakening one hundred years before the birth of Francis Bacon, but it is in no sense true of the Arabic scientists or of the men of Bacon's own and preceding generation.

For example, Alexander is said to have sent to Aristotle from Babylon the records of more than 1,900 years of astronomical observation. The founding of the great university of Alexandria, although it occurred after the Macedonian conquest, was due quite as much to the Jews and the Egyptians as to Greek influence. It was in this school that Euclid and Archimedes were trained, and the science of astronomy was carried forward from the earlier Babylonian beginnings. Such Greek science as had been carried over into the Roman period was virtually dead after Justinian prohibited the teaching of philosophy and closed its schools in Athens, A.D. 529. Singer, in "The Dark Ages and the Dawn," says that with the death of Theon of Alexandria, about the year 400, we part altogether with the impulse of the science of antiquity.

For several hundred years reason was abandoned for faith throughout Christian countries. These were the so-called Dark Ages. Meanwhile Arabia became the world's center of scientific research. Al Mamun, or Al Maimon, who was Caliph of Bagdad from 813 to 832, determined the sphericity of the earth and calculated its circumference from three measurements of one degree of the arc of its meridian. This was more than 650 years before Columbus.

Almaimon also collected great libraries and museums and made Bagdad the center of the world's intelligence. He also determined the obliquity of the Ecliptic. Alhazen, who died in Cairo in 1038, became the father of geometrical optics and of perspective, understood atmospheric refraction and its influence on the morning and evening twilight, explained the apparent increase in size of the sun and moon when seen near the horizon, located the conjugate foci of spherical mirrors and made many more important discoveries.

Before 1080 we have five Arabic determinations of the obliquity of the Ecliptic, all lying between 23: 34′ and 23: 35′: 52′. While the rest of Europe was hidden in the clouds of ignorance of the Dark Ages, the Saracens were covering Spain with universities, observatories and libraries. Draper, in "The Intellectual Development of Europe," says:

When Europe was hardly more enlightened than Caffraria is now the Saracens were cultivating and even creating science. Their triumphs in philosophy, mathematics, chemistry, medicine, proved to be more glorious, and therefore more important, than their military actions had been.

All these facts seem to have been unknown to Francis Bacon, although he boasted that he had taken all knowledge for his field.

Coming down to Bacon's own country, the first great English scientist of whom we have knowledge was Roger Bacon (1214–1292), who lived 350 years before Francis Bacon. Roger Bacon was without question the most learned man of his generation in the known world. Although he was a great admirer of Aristotle, whom he calls the greatest philosopher the world has produced, he was likewise a thorough student of Arabian science, and especially of Alhazen.

Roger Bacon was a Franciscan monk. He was educated at Oxford and Paris and taught in Oxford for a number of years. He states in his "Opus Tertium" that he devoted more than twenty years to the study of languages and sciences. He writes:

I sought the friendship of all the wise men among the Latins; and I caused young men to be trained in languages, in geometrical figures, in numbers, in the construction of tables, in the use of instruments, and in many other necessary things. . . . During this time I spent more than two thousand pounds in those things, and in the purchase of books and instruments.

His fame as a scientist became very great. His students called him Doctor Mirabilis. His teaching incurred the suspicion of his superiors in the Franciscan Order, and at the age of 43 years he was exiled to Paris and placed under restraint in the house of his order. He remained there for ten years, during which time he was forbidden to write anything for publication.

Meantime Pope Clement IV had learned of Bacon's fame and had ordered him to send for the perusal of His Holiness copies of all his writings.

Prior to this time Bacon had written but little, but in compliance with the Pope's orders he wrote in one year his "Opus Majus," "Opus Minus" and "Opus Tertium," which with his other writings he sent to the Pope. The "Opus Majus," the most recent English translation of which is a two-volume book of more than eight hundred pages, is in its essentials a defense of philosophical and scientific knowledge and explains what Bacon regarded as the true method of scientific investigation. Accordingly, it is comparable with Francis Bacon's "Advancement of Learning" and "Novum Organum," the former of which was a treatise on the importance of learning prepared for the apparent purpose of exhibiting the erudition of the author to King James, and the second for the avowed purpose of proposing a new method of acquiring a true knowledge of nature. A comparison of the "Opus Majus" and the "Novum Organum" has proved both interesting and enlightening.

It is the first book of the "Novum Organum" on which the fame of Francis Bacon as a scientific reformer largely rests. In it he undertakes to describe and classify the errors and difficulties which beset the human mind in the search for truth. The second book, which attempts to illustrate the true method of scientific investigation, has never had any standing among scientific workers. Let us, then, briefly compare his analysis in Book I with that given by Roger Bacon three and one half centuries earlier.

Francis Bacon begins by calling attention to the limitations of the human mind. He says:

Man as the minister and interpreter of nature, does and understands as much as his observations on the order of nature, either with regard to things or the mind, permit him, and neither knows nor is capable of more. . . . The subtility of nature is far beyond that of sense or of the understanding, so that the specious meditations, speculations and theories of mankind are but a kind of insanity, only there is no one to stand by and observe it.

Regarding the fallibility of human reason, Roger Bacon had said:

It is certain that never, before God is seen face to face, shall a man know anything with final certainty. It is impossible therefore for a man to attain perfect knowledge in this life, and it is exceedingly difficult for him to attain imperfect truth, and he is very prone and disposed toward whatever is false and empty; wherefore man ought not to boast of his knowledge, nor ought anyone to magnify and extol what he knows. For his knowledge is small and of little value in comparison with what he does not understand, but believes, and still smaller in comparison with that of which he is ignorant and does not know either by faith or knowledge.

And some seventeen hundred years before Roger Bacon Anaxagoras had complained as follows:

Nothing can be known; nothing can be learned; nothing can be certain; sense is limited; intellect is weak; life is short.

Francis Bacon begins the "Organum" with a series of "aphorisms," sometimes of several pages in length. These aphorisms consist of 130 numbered articles and occupy 52 pages in my copy of the "Organum." He classifies the errors and hindrances to the acquirement of knowledge under the name of "Idols." He says:

The idols and false notions which have already preoccupied the human understanding, and are deeply rooted in it, not only so beset men's minds that they become difficult of access, but even when access is obtained will again meet and trouble us in the instauration of the sciences, unless mankind when forewarned guard themselves with all possible care against them.

Aphorism 39.—Four species of idols beset the human mind, to which (for distinction's sake) we have assigned names, calling the first idols of the tribe, the second idols of the den, the third idols of the market, the fourth idols of the theater.

Aphorism 41.—The idols of the tribe are inherent in human nature and the very tribe or race of men; for men's sense is falsely asserted to be the standard of things; on the contrary, all the perceptions both of the senses and the mind bear reference to man and not to the universe, and the human mind resembles those uneven mirrors which impart their properties to different objects from which rays are emitted and distort and disfigure them.

This is a virtual repetition of his previous statement of the fallibility of human reason. Accordingly, the idols of the tribe are incapable of elimination.

Aphorism 42.—The idols of the den are those of each individual; for everybody (in addition to the errors common to the race of man) has his own individual den or cavern, which intercepts and corrupts the light of nature, either from his own peculiar and singular disposition, or from his intercourse with others, or from his reading, and the authority he acquires from those whom he reverences and admires, or from the different impressions produced on the mind, as it happens to be preoccupied and predisposed, or equable and tranquil, and the like; so that the spirit of man (according to its several dispositions) is variable, confused, and, as it were actuated by chance; and Heraclitus said well that men search for knowledge in lesser worlds, and not in the greater or common world.

Aphorism 43.—There are also idols formed by the reciprocal intercourse and society of man with men, which we call idols of the market, from the commerce and association of men with each other; for men converse by means of language, but words are formed at the will of the generality, and there arises from a bad and inept formation of words a wonderful obstruction to the mind.

Nor can the definitions and explanations with which men are wont to guard and protect themselves in some instances afford the complete remedy—words still manifestly force the understanding, throw everything into confusion and lead mankind into vain and innumerable controversies and fallacies.

Aphorism 44.—Lastly, there are idols which have crept into men's minds from the various dogmas of peculiar systems of philosophy, and also from the perverted rules of demonstration, and these we denominate idols of the theater, for

we regard all the systems of philosophy hitherto received or imagined as so many plays brought out and performed, creating fictitious and theatrical worlds. Nor do we speak only of the present system, or of the philosophy and sects of the ancients, since numerous other plays of a similar nature can still be composed and made to agree with each other, the causes of the most opposite errors being generally the same. Nor again do we allude merely to general systems, but also to many elements and axioms of sciences which have become inveterate by tradition, implicit credence and neglect.

These five aphorisms contain the gist of Francis Bacon's analysis of the errors and hindrances in human efforts to acquire a knowledge of nature. Roger Bacon had specified somewhat the same difficulties much more concisely. He says:

> Now there are four chief obstacles in grasping truth, which hinder every man, however learned, and scarcely allow any one to win a clear title to learning, namely, submission to faulty and unworthy authority, influence of custom, popular prejudice, and concealment of our own ignorance accompanied by an ostentatious display of our knowledge.

In the first-mentioned three of these hindrances Roger Bacon has stated virtually all the difficulties mentioned in Francis Bacon's essay on idols and has added a fourth hindrance which seems never to have been appreciated by the author of "Novum Organum." In regard to this fourth obstacle to the attainment of truth, Roger Bacon says:

> He especially is bereft of reason who makes a display of his knowledge and tries to publish it abroad as something marvelous.

Apart from the dissertation on idols, practically the whole of Book I of the "Organum" is taken up in criticizing the methods of scientific investigation proposed or practiced by the predecessors of Francis Bacon.

He says:

> It is vain to expect any great progression in the sciences by superinducing or engrafting new matters upon old. An instauration must be made from the very foundations, if we do not wish to revolve forever in a circle, making only some slight and contemptible progress.

On the other hand, Roger Bacon says:

> We of a later age should supply what the ancients lacked, because we have entered into their labors, by which, unless we are dolts, we can be aroused to better things, since it is most wretched to be always using old discoveries and never to be on the track of new ones.

Newton, in the generation following Francis Bacon, recognized the value of the discoveries of his predecessors when he said, "If I saw further it was because I stood on giant shoulders."

Since Francis Bacon devotes so much effort to showing that all scientific research prior to his time was worthless, it has seemed worth while to inquire into the results of some of these researches with which Bacon should have been familiar if he was to lead a scientific reformation.

One hundred and nine years before the birth of Francis Bacon one of the world's greatest geniuses was born in Florence, Italy. Leonardo da Vinci (1452–1519) became famous as a painter, sculptor, architect, engineer, anatomist, botanist and astronomer, and he was also the greatest physicist of his century. Leonardo, in telling of his methods of research, says:

> In undertaking scientific investigations I first plan a few experiments, because it is my design to base the problem on experience, and then to determine why the bodies in question are constrained to act in a given manner. This is the method that one must adopt in all researches.

Here we have a much clearer statement of the purpose of scientific induction than is given in the "Organum," but with da Vinci it was only the first step in an investigation instead of the whole process.

Da Vinci will hardly be accused of deriving his method from the writings of Greek philosophers, since he is said

to have been illiterate even in his own language, and did not acquire even an elementary knowledge of Latin till well on in life.

Francis Bacon everywhere refers to practical inventions as the highest type of scientific investigation, and Leonardo is still recognized as one of the world's greatest inventors. His death occurred only one hundred years before the writing of the "Organum."

Another forerunner of Bacon whose opinions and methods seem not to have been dependent upon the Greek philosophers was Paracelsus (1493–1540). Stillman tells us in his "Paracelsus":

> The influence of Paracelsus on Chemistry was epoch-making. By pointing out a rational and promising field for chemical activity and by his own successful application of chemically prepared remedies he inaugurated a movement which has continued without interruption and with increasing importance to the present day.

Dr. Thomas Thomson, in his "History of Chemistry" (1830), says:

> It is from the time of Paracelsus that the true commencement of chemical investigation is to be dated.

Locy, in his "Growth of Biology," calls Paracelsus the most original medical thinker of the century. Stillman tells us:

> The great popularity and consequent influence upon the time of the works of Paracelsus is evidenced by the bibliography of his printed works compiled by Sudhoff, in which no less than two hundred and fifty are recorded as appearing before 1600.

The writings of Paracelsus must be included among the "few modern attempts at scientific investigation" which Bacon rated as of small importance.

Coming nearer to Bacon's own time, we have the anatomist Vesalius (1514–1564), who died three years after Bacon was born. Singer says of Vesalius ("The Dark Ages and the Dawn," p. 157):

> Taken as a whole, his work is one of the most marvelous efforts of scientific observation that has ever been launched upon the world.

Vesalius's great work on the structure of the human body appeared in 1543, seventy-seven years before the "Organum." Locy, in "Biology and Its Makers," says:

> The book of Vesalius laid the foundation of modern biological science. It is more than a landmark in the progress of science—it created an epoch.

Another famous scientist whose work should have been known to Bacon was Johann Baptista van Helmont, a native of Brussels, who, Stillman tells us, was the most prominent chemist of the first half of the seventeenth century. Van Helmont visited London in 1604–1605 while Bacon was writing "The Advancement of Learning" and was received with honor.

Turning to another field of scientific research, in 1543, eighteen years before the birth of Bacon, Nicholaus Copernicus published his great work, "De Orbium Coelestium Revolutionibus," in which he set forth the evidence for the heliocentric theory of the solar system. This book led to one of the greatest conflicts ever waged in the warfare of science, which conflict had its climax in Bacon's lifetime. Two years before the publication of "Novum Organum" the works of Copernicus were ordered burned, and Galileo was in the midst of his second and fatal controversy with the Inquisition.

In "The Advancement of Learning" Bacon recites a number of exploded dogmas, among them "the absurdity of which have thrown men upon the extravagant idea of the diurnal motion of the earth, an opinion which we can demonstrate to be most false."

This was written five years after the burning of Giordano Bruno, who had

been in England twenty years before, had written some of his most important books while there, had held a disputation with some learned doctors at Oxford over the rival merits of the Ptolemaic and the Copernican theories of the universe and had written and published in England an exposition of the Copernican theory.

Later, Bacon seems to regard the diurnal motion of the earth as at least a debatable question. In the "Organum," which was written two years after the publication of Kepler's Laws, and after Bacon had accepted the fact of the revolution of the satellites of Jupiter, he says, speaking of the supposed revolution of the heavens about the earth:

The motion in question is, according to common and long received opinion, considered to be that of the heavenly bodies. There exists however, with regard to this, a considerable dispute between some of the ancients as well as moderns, who have attributed a motion of revolution to the earth. A much more reasonable controversy perhaps exists (if it be not a matter beyond dispute) whether the motion in question (on the hypothesis of the earth's being fixed) is confined to the heavens, or rather descends and is communicated to the air and the water.

What this means, I do not know, unless it refers to the trade winds and some of the ocean currents which had been mentioned by the early navigators; but it certainly does not mean that Bacon was an advocate of the heliocentric theory or that he has added to the development of modern astronomy.

Although not favorably impressed by Galileo's arguments in the field of astronomy, Bacon seems to have been influenced by some of his experiments in mechanics. After Galileo's demonstration that all bodies fall with equal velocities except as they are hindered by a resisting medium, Bacon, after stating that twenty pounds of lead fall no faster than a single pound, says:

Inquire whether the quantity of a body may be so increased as that the motion of gravity shall be entirely lost, as in the globe of the earth which hangs pendulous without falling. Quaere, therefore whether other masses may be so large as to sustain themselves? For that bodies should move to the center of the earth is a fiction; and every mass of matter has an aversion to local motion, till this be overcome by some stronger impulse.

And Macaulay tells us that Bacon had an amplitude of comprehension such as has never yet been vouchsafed to another human being. At least, there was a development of modern astronomy before Bacon wrote the "Organum." Besides the arguments of Copernicus, Tycho Brahé had carried on his famous observations at Uranienburg and elsewhere, Kepler had computed the laws of planetary motion, Galileo had shown the revolution of Jupiter's satellites and the phases of Venus.

It is not even necessary to go outside the circle of Bacon's acquaintances to show that science was not contemptible before the publication of either of his books. In 1600, William Gilbert, chief physician to Queen Elizabeth, published his "De Magnete," the first great work on physical science which was produced in England. Galileo, who is often called the originator of modern science, says of Gilbert's book that it is "great to a degree to be envied." Dr. Thomas Young, who was regarded as the greatest scholar of his day in England, the interpreter of the Egyptian inscriptions, the founder of the undulatory theory of light and the first man to measure the wave-length of light, published a course of lectures on "Natural Philosophy and the Mechanical Arts" in 1907. In these lectures he gives especial attention to the history of the development of physical science. He says of William Gilbert:

The first of the moderns whose discoveries respecting the properties of natural bodies excite our attention by their novelty and impor-

tance is Dr. William Gilbert, of Colchester; His work on Magnetism published in 1590, contains a copious collection of valuable facts, and ingenious reasonings. He also extended his researches to other branches of science and, in particular to the subject of electricity.

Gilbert not only published the results of his investigations which established that the earth, itself, is a great magnet, and nearly all the other facts known about magnetism until the discovery of electromagnetism more than two hundred years later, but he described his method of research. In the opening paragraph of his preface he says:

Since in the discovery of secret things and in the investigation of hidden causes, stronger reasons are obtained from sure experiments and demonstrated arguments than from probable conjectures and the opinions of philosophical speculators of the common sort; therefore to the end that the noble substance of that great loadstone our common mother (the earth) still quite unknown, and also the forces extraordinary and exalted of this globe may the better be understood, we have decided first to begin with the stony and ferruginous matter, and magnetic bodies, and the parts of the earth that we may handle and perceive with the senses; then to proceed with plain magnetic experiments and to penetrate to the inner parts of the earth.

In another place he says:

This natural philosophy is almost a new thing, unheard of before; A very few writers have simply published some meager accounts of certain magnetic forces. Therefore we do not at all quote the ancients and the Greeks as our supporters, for neither can paltry Greek argumentation demonstrate the truth more subtly nor Greek terms more effectively, nor can both elucidate it better. Our doctrine of the loadstone is contradictory of most of the principles and axioms of the Greeks.

At the time of publication of "De Magnete" Galileo, who was twenty-four years younger than Gilbert, had already made his memorable experiment on falling bodies and was lecturing in Padua and laying the foundations of the science of mechanics.

Another contemporary of Bacon who ranks among the most distinguished of the world's scientific investigators was William Harvey (1578–1667). Harvey was seventeen years younger than Bacon, and began his practice of medicine in 1602, after graduating from Cambridge and spending four years at the University of Padua under the special instruction of Fabricius. Besides his medical practice he gave public lectures on anatomy while he was carrying on extensive investigations in various fields of biology. He became Bacon's personal physician, which must have given Bacon an opportunity to know something of the biological science of his day had he been so inclined. During this period Harvey demonstrated the circulation of the blood through the arteries and veins and lectured on this topic, though his great work, "De Motu Cordis et Sanguinis," was not published until 1628.

Locy ("Biology and its Makers," p. 52) says of Harvey's influence on science:

He was a comparative anatomist as well as a physiologist and embryologist; he had investigated the anatomy of about sixty animals and the embryology of insects as well as vertebrates, and his general influence in promoting biological work was extensive. His work on the movement of the blood was more than a record of careful observations; it was a landmark in progress.

While Harvey must have been well acquainted with Bacon, there is no indication that his methods of research were influenced by this acquaintance. Bacon tells us in "Advancement of Learning":

Medicine has been rather professed than labored and yet more labored than advanced, as the pains bestowed thereon were rather circular than progressive; for I find great repetition and but little new matter in the writers of physic.

Aubrey's "Biography of Harvey," quoted in Locy's "Growth of Biology," says:

He (Harvey) had been physitian to the Lord Ch. Bacon, whom he esteemed much for his wit and style, but would not allow to be a great philosopher. Said he to me, "He writes philosophy like a Lord Chancellor."

In this very inadequate review of some of the scientific work in Europe prior to the publication of the "Novum Organum" mention has been made of at least ten men who are still regarded as world leaders in their fields of investigation, while nothing has been said of their numerous contemporaries whose names appear in every history of the science of that period.

Lord Bacon gives no indication that he recognized the great scientific revival of his own generation. He seldom refers to any scientific investigator except Gilbert, and to him only contemptuously. He does recognize Galileo to the extent of wondering why he does not discover how large a body must be in order that gravitation may cease to act upon it; but he makes frequent mention in both "The Advancement of Learning" and the "Organum" of "Gilbert who has written a painful and elaborate work upon the magnet." He says: "So the alchemists have made a philosophy from a few experiments of the furnace, and Gilbert another out of the loadstone."

He refers to men who "waste all their time on probing some solitary matter, as Gilbert on the magnet and the alchemists on gold."

He tells us that "The electric energy (of which Gilbert and others after him have told so many fables) is only the energy excited by gentle friction."

Why Bacon selected Gilbert as his especial example for adverse criticism he does not tell us, and it is the purpose of this paper to let Bacon tell his own story. However, it is a fact that Gilbert had proposed a method of scientific investigation and had demonstrated its efficiency twenty years before the publication of the "Organum," and that although Gilbert had been known to be capable of self defense during his lifetime, he had died two years before the publication of "The Advancement of Learning," and eighteen years before the "Organum."

Bacon tells us in his introduction to the "Organum":

Our method, though difficult in its operation, is easily explained. It consists in determining the degree of certainty, whilst we, as it were, restore the senses to their former rank, but generally reject that operation of the mind which follows close upon the senses, and open and establish a new and certain course for the mind from the first actual perceptions of the senses themselves.

Let me quote a few excerpts from the list of aphorisms:

Aphorism 8.—Even the effects already discovered are due to chance and experiment, rather than to the sciences; for our present sciences are nothing more than peculiar arrangements of matters already discovered, and not methods for discovering or plans for new operations.

Aphorism 11.—As the present sciences are useless for the discovery of effects, so the present system of logic is useless for the discovery of the sciences.

Aphorism 19.—There are and can exist but two ways of investigating and discovering truth. The one hurries on rapidly from the senses and particulars to the more general axioms, and from them as principles and their supposed indisputable truth, derives and discovers the intermediate axioms. This is the way now in use. The other constructs its axioms from the senses and particulars, by ascending continually and gradually, till it finally arrives at the more general axioms, which is the true, but unattempted way.

In Aphorism 69 Bacon gives a sort of summary of his doctrine as follows:

In the first place, the impressions of the senses are erroneous, for they fail and deceive us. We must supply defects by substitutions, and fallacies by their correction. Secondly, notions are improperly abstracted from the senses, and intermediate and confused when they ought to be the reverse. Thirdly, the induction that is employed is improper, for it determines the principles of science by simple enumeration, without adopting exclusions and resolutions, or just separations of nature. Lastly, the usual method of discovery and proof, by first establishing the most general propositions, then ap-

plying and proving the intermediate axioms according to them, is the parent of error and the calamity of every science.

It is difficult for one so poorly equipped in philosophical methods as myself to distinguish clearly between this method which Bacon condemns and the method which he recommends in his Aphorism 117.

Our course and method, however (as we have often said and again repeat), are such as not to deduce effects from effects, nor experiments from experiments (as the empirics do), but in our capacity as legitimate interpreters of nature, to deduce causes and axioms from effects and experiments; and new effects and experiments from these causes and axioms.

And although anyone of moderate intelligence and ability will observe the indications and sketches of many noble effects in our tables and inventions (which form the fourth part of the *Instauration*) and also in the examples of particular instances cited in the second part, as well as in our observations on history (which is the subject of the third part); yet we candidly confess that our present natural history, whether compiled from books or our own inquiries, is not sufficiently copious and well ascertained to satisfy, or even assist, a proper interpretation.

Here Bacon seems to admit that not even he has yet been able to devise anything which will assist in the interpretation of nature, though in his 73d aphorism he says:

Of all signs there is none more certain or worthy than that of the fruits produced, for the fruits and effects are the sureties and vouchers, as it were, for the truth of philosophy. . . . We think some ground of hope is afforded by our own example, which is not mentioned for the sake of boasting, but as a useful remark. Let those who distrust their own powers observe myself, one who have amongst my contemporaries been the most engaged in public business, who am not very strong in health (which causes a great loss of time), and am the first explorer of this course, following the guidance of none, not even communicating my thoughts to a single individual; yet having once firmly entered the right way, and submitting the powers of my mind to things I have somewhat advanced (as I make bold to think) the matters I now treat of.

Finally, Bacon tells us near the close of Book I that what he has said so far is merely to convince his readers that no one has yet acquired the true art of interpreting nature. In "The Advancement of Learning" he had said:

Lastly, I may lament that no fit men have been engaged to forward those sciences which yet remain in an unfinished state. To supply this want it may be of service to perform, as it were, a lustrum of the sciences, and take account of what has been prosecuted and what omitted.

Yet Bacon lived during the most productive period of scientific research the world had ever known.

Since Bacon concludes that in Book I he has convinced his readers of the necessity of a new method of interpreting nature, he proceeds in Book II, which in my copy consists of 102 pages, to describe and illustrate his method by instructions for investigating the "Form of Heat." Bacon's use of the term "form" is not perfectly clear to me. I will quote his definition.

The form of any nature is such, that when it is assigned the particular nature infallibly follows. It is therefore, always present when that nature is present, and universally attests such presence, and is inherent in the whole of it. The same form is of such a character, that if it be removed the particular nature infallibly vanishes. It is therefore absent whenever that nature is absent, and perpetually testifies such absence, and exists in no other nature. Lastly, the true form is such, that it deduces the particular nature from the source of essence existing in many subjects, and more known (as they term it) to nature, than the form itself. Such then is our determination and rule with regard to a general and perfect theoretical axiom, that a nature be found convertible with a given nature, and yet such as to limit the more known nature, in the manner of a real genus.

The aim of Bacon's proposed system, as nearly as I can make it out, is the discovery of these "forms" in nature. This is as far as possible from my understanding of the nature of physical science, which is the investigation of mechanical relations between the various phenomena of the physical universe.

Bacon seems to use the term nature somewhat in the sense in which we use the term property. He speaks of a body as an aggregate of simple natures and describes the natures of gold as yellow, heavy, of a certain weight, malleable and ductile to a certain extent, and the like. Thus he means by bodies of the same natures what we would describe as bodies having the same properties. The "form" of a body or of a phenomenon seems, then, to mean something upon which all its various properties depend. It suggests the ancient idea of the spirit or essence of a body or an event.

It has seemed to me that the most nearly understandable of the various attempts at explaining Bacon's meaning which I have read is found in Adamson's article on Francis Bacon in the ninth and following editions of the "Britannica." Adamson says:

> It appears clear that in Bacon's belief the true function of Science was the search for a few fundamental physical qualities, highly abstract and general, the combination of which give rise to the simple natures and complex phenomena around us.

Looked at from this standpoint it is no wonder that Bacon saw nothing praiseworthy in the science of his day. Galileo was not looking for forms, but was trying to find out the relation between the velocity and the time of free fall of a body, or the relation between the time of vibration of a pendulum and its length, or the question of the rotation of the earth rather than the revolution of all the heavenly bodies around it. Gilbert was determining the location of the great magnet which controlled the orientation of the magnetic needle. Harvey was determining the character of the movement of the blood in the arteries and veins. None of the investigators of his day was trying to determine "the form of heat" or motion or magnetism or gravity. Even Newton, one generation later, was determining only that gravitation was the same throughout the solar system. Accordingly, when Bacon tells us, "Physics treats of the principles of things, the structure of things and the variety of things," he is not speaking of any physics which has existed in modern times. Necessarily, his influence on modern physics has been nil.

This assertion would seem still more certain were we to follow through the 95 pages of Bacon's description of the proper method for determining the "form of heat."

He first gives a table of twenty-seven "Instances Agreeing in the Form of Heat." These are of various kinds, as "The heat of the sun," "Flame of every kind," "Natural warm baths," "Strong spirits of wine when poured upon whites of eggs causing them to grow hard and white," "Strong vinegar and all acids on any part of the body not covered by epidermis," "Aromatic substances which, while not hot to the touch are found by the tongue and palate to be warm when chewed," and many others.

Later he gives us a "Table of the Degrees or Comparative Instances of Heat." In this table he gives forty-one examples. Some of these do not show the accurate observation which Macaulay attributes to Bacon. Thus he says in Example 39:

> A brick or stone or hot iron, plunged in a basin of cold water and kept there for a quarter of an hour or thereabouts, retains such a heat as not to admit of being touched.

He also tells us that water freezes more easily after having been gently warmed.

He then gives examples of the "Exclusive Table, or the Rejection of Natures from the Form of Heat." In this table he tells us what natures to reject in deciding upon the form of heat because they are not common to all bodies which partake of this form. He tells us,

> It must be observed that the form of anything is inherent (as appears clearly from our premises), in each individual instance in which

the thing itself is inherent, or it would not be a form. No contradictory instance therefore can be allowed.

As a final result of his discussion regarding the form of heat Bacon says; "From the instances taken collectively as well as singly, the nature whose limit is heat seems to be motion."

This induction Bacon terms "The First Vintage of the Form of Heat," that is, it is the primary induction which is to be used in building up other inductions. Motion is not "the form of heat," but only one of the "natures" of that form. Nevertheless, Will Durant tells us in "The Story of Philosophy," "He (Bacon) finds after long analysis an exact correlation between heat and motion; and this conclusion that heat is a form of motion constitutes one of his few specific contributions to natural science."

A relation of heat to some form of motion was suspected, not only by Bacon, but by Descartes, Amontons, Boyle, Hooke and Newton, and was finally demonstrated by Rumford and Davey nearly two hundred years later. However, it took fifty years longer to demonstrate that, to use our present terminology, heat is a form of energy, still from Bacon's definition energy is not "the form of heat."

In marked contrast to Francis Bacon's proposed system of successive inductions is Roger Bacon's statement of the proper method of scientific investigation. In the copy of "Opus Majus" which is before me he devotes fifty-one pages to a discussion of the method of experimental science. He tells us:

This science has three leading characteristics with respect to other sciences. The first is that it investigates by experiment the notable conclusions of all those sciences. For other sciences know how to discover their principles by experiments, but their conclusions are reached by reasoning drawn from the principles discovered. But if they would have a particular and complete experience of their own conclusions, they must have it with the aid of this noble science. . . . For there are two modes of acquiring knowledge, namely, by reasoning and by experience. Reasoning draws a conclusion, and makes us grant the conclusion, but does not make the conclusion certain, nor does it remove doubt so that the mind may rest on the intuition of truth, unless the mind discovers it by the path of experience. . . . Aristotle's statement, then, that proof is reasoning that causes us to know is to be understood with the proviso that the proof is accompanied by its appropriate experience, and is not to be understood as the bare proof. Reasoning does not suffice, but experience does. . . . He therefore who wishes to rejoice without doubt in regard to the truth's underlying phenomena must know how to devote himself to experiment.

As a comparison with Francis Bacon's investigation of the form of heat, we may consider Roger Bacon's explanation of the rainbow and the coronas sometimes seen around the sun and the moon.

He begins by developing the geometrical optics of the rainbow and the solar coronas as he understands them. He shows that the rainbow is due to light reflected from water drops, as may be seen in mist and sprays of water and in dew drops, while coronas and haloes are due, as he believes, to refraction. He is not clear about the nature of diffraction, as who can be without a knowledge of the undulatory theory? However, he describes the formation of diffraction fringes around a small aperture through which light is observed.

He describes the position of the rainbow with reference to the sun, and concludes that the sun, the eye of the observer and the center of the arc of the rainbow must be in the same straight line, also that the angle made by the rays from the circumference of the rainbow arc and its central axis at the eye of the observer must be 42 degrees, and hence that no rainbow can be visible to one when the sun behind him is more than 42 degrees above the horizon, and he discusses the times of year when rainbows may be seen at different latitudes on the earth.

In this calculation he does not take into consideration the double refraction and reflection of the light rays from the two surfaces of the water drops, and accordingly the different angles at which the cone of rays may reach the eye from drops of different radius.

He is not able to explain the separation of colors in the rainbow nor in the spectrum produced by a prism, as no one was until Newton showed that the various colors were properties of the sunlight. Bacon thought they were due to some property of the eye, as their recognition is now known to be.

One of the questions which interested Bacon, and which he could not answer to his own satisfaction, was the cause of the scintillation of the stars. He thought of the possibility of refraction due to some unsteady, non-homogeneous body between us and the stars, but he believed that refraction occurred only when light passed from one medium to another, and could not be due to the atmosphere after light had once entered it. He describes the effect of the difference in density of refracting media upon the direction of bending of oblique rays in passing from one to the other, but does not recognize the effect of density variation within a given medium.

Bacon taught that while the rainbow was due to reflection the coronas and haloes around the sun are due to refraction, though he could not specify the refracting surfaces as we do at the present time. So far as was possible with the knowledge of his time, his explanation of the rainbow is a masterpiece, though his geometrical optics was largely derived from the writings of Alhazen. He refrained from proposing explanations of phenomena which he could not verify, and was consistent with his theory of experimental science, namely, that his conclusions as well as the data for his inductions must be verified by experience. This is the one step in the scientific method which seems to have been first insisted upon by Roger Bacon. By its adoption the modern scientific method became complete. Nothing has since been added to it.

The thorough mastery of the subject of geometrical optics by Bacon is shown in his statements of the possibility of the construction of the telescope and microscope. At the close of his report on optical science in the "Opus Majus" he says:

> The wonders of refracted vision are still greater; for it is easily shown by the rules stated above that very large objects can be made to appear very small, and the reverse, and very distant objects will seem very close at hand, and conversely. For we can so shape transparent bodies and arrange them in such a way with respect to our sight and objects of vision, that the rays will be refracted and bent in any direction we desire, and under any angle we wish. We shall see the object near or at a distance. Thus from an incredible distance we might read the smallest letters and number grains of dust and sand owing to the magnitude of the angle under which we viewed them, and very large bodies very close to us we might scarcely see because of the smallness of the angle under which we saw them, for distance in such vision is not a factor except by accident, but the size of the angle is.

One can only conjecture what Roger Bacon might have done for the cause of science had he been allowed to follow up his proposed method, but only three years after he was freed from his confinement in Paris the daring and frankness of his teaching caused his arrest and imprisonment for fourteen more years, and he was set free only at the age of 77, and a short time before his death. As it is, he seems to have been the first man to state clearly the scientific method of thinking which has transformed a large part of the civilization of the world in the past three hundred years. In the development of this method of thinking the world has known only one Bacon, and his name was not Francis.

A PRAGMATIST EXAMINES THE DISCARD OF MECHANISTIC PSYCHOLOGY

By Dr. BENJAMIN R. SIMPSON
PROFESSOR OF EDUCATIONAL PSYCHOLOGY, WESTERN RESERVE UNIVERSITY

College studies of to-day at their best make a vital and varied appeal to the youth of real intellectual ability. The physical sciences point the way to new achievements in radio, television, synthetic chemistry—products of the mind of man. History illumines the human drama as it has been enacted in historic times, with its interplay of motives which have turned the tide of human destiny hither and yon. Biography selects the unusually significant or picturesque human life and concentrates upon the interpretation of its struggles and achievements. The novel and the drama portray the complexities of human emotion. Shakespeare is the acknowledged master in the portrayal of human nature.

Thus the arts, humanities and sciences, which constitute so large a part of a modern college curriculum, seem to illuminate the life of man and the product of his intellectual explorations. And what of psychology? Should not psychology be counted upon to lead the eager student into the inner sanctuary, the scientific study of man himself? Presumably this should deal with what is most significant in man—his impelling drives and purposes, his satisfactions and disappointments, his learning, the attitudes which may culminate in a Napoleonic career, and how more intelligent direction of learning may be counted upon to result in greater human values for all parties concerned. One wants to know how groups, both local and national, may hope to achieve more lasting forms of satisfaction and avoid destructive conflicts. Primitive man, to be sure, had to struggle with problems of a physical sort, but now come problems of adjustment of the individual within himself and with his neighbor. What a bonanza to the youthful intellect—the science which gives the accumulated researches of the masters in this study of the life of man!

If such is the expectation, what must be the disillusionment when the eager student turns the pages written by the self-admitted leader of the only (?) scientific movement in present-day psychology and finds that there is in reality no such thing as mind or consciousness; that "Belief in the existence of consciousness goes back to the ancient days of superstition and magic," and that the scientific psychologist has "dropped from his scientific vocabulary all subjective terms such as sensation, perception, image, desire, purpose, and even thinking and emotion as they are subjectively defined." Also that other psychologists not so doing are without the pale and barren of production. Emotion, for example, becomes "an hereditary pattern reaction involving profound changes of the bodily mechanism as a whole, but particularly of the visceral and glandular systems." As one critic has expressed the situation which must face the student in his attempt to understand such a human emotion as fear: "Fear is that psycho-galvanic-blood-pressure-breathing-ratio score falling within the middle fifty per cent. of the scores made by any given group of subjects exposed to the firegong-electric punishment test, known as Shock U (copies at the bookstore, 7 cents each)." Presumably the student would be advised that he must hence-

forth be on guard against thinking that he has ever felt fear as a mental state; that such is a mere delusion, and that his emotion is in reality only a bodily reaction.

Nor is that the worst of the story, for there is no such thing as human choice or human purpose. Lincoln was a mechanical robot and, as such, could not have done other than he did, for his responses were inevitably determined by the stimuli which played upon him. What becomes of the study of Lady MacBeth or of Jean Valjean!

How is one to account for such a travesty as this? Surely science must start with what is already accepted universally or prove it false. It must start with life and apply to life in a way that works. Otherwise it fails to be a contribution and fails to meet the criterion of science. Such psychology as the above explains nothing. It demolishes everything. A scientific theory is accepted only because it works, and such theories as the above do not work. They are not acted upon by the very persons who teach them. What behaviorist tries to persuade his friend who has just broken his leg that consciousness of pain is a mere delusion, or the judge in court that the accused at the bar of justice was a helpless mechanical puppet solely at the mercy of the stimuli playing upon him! Can it be that this belief is just a new fashion and as foolish as some other fashions supposedly less intellectual have been? Can it be due to a blind following of one point of view to the exclusion of all other considerations?

II

The whole story is a long one, but in this connection consideration will be limited to conditioning—its genesis, significance and implications. It is the great Russian physiologist, Ivan Pavlov, who is generally credited with being the originator of the conditioned reflex technique of experimentation. His contributions were received in medical circles with the greatest interest for three decades. It is he who uncovered, for example, the facts which gave the world the illuminating diagnosis of *nervous indigestion.*

Yet Pavlov, since he was the large-caliber sort of man, freely handed the credit to an American as the first to use objective methods such as he was putting into service in 1904 in his study of animal learning. He referred of course to the classic work of E. L. Thorndike, of Teachers College, New York, on "Animal Intelligence," published in 1898. Thorndike's method was to observe and record the objective behavior responses of the animal as it learned, and also to record the situation responsible for calling forth the response. This technique supplied the famous S-R formula, which has since proved so useful in all studies of learning.

Such a study had to be objective and free from introspection on the part of the subject, for one can not very well ask a cat to report upon its mental states when learning. One must rather observe and record its behavior as a chemist observes and records the behavior of the contents of his test-tube.

Meanwhile in 1904 Pavlov began his work in the study of digestion and ran upon some behavior which appeared to be psychological which he could study to advantage by his objective, highly specialized methods. Pavlov emphasized the fact that if salivation is to occur, the *organism* must always be in a state of *readiness* for such a response. The animal must be hungry, and he must be alert. A dog that was satiated or one that was sleepy would fail to respond or to learn. In other words, the condition of the organism which made the response as well as the external stimulus must be duly considered as a factor determining the learning.

Also a principle of general and fundamental significance appeared to be in

evidence, namely, that any arbitrary stimulus might be made to call forth the given response, provided it were presented simultaneously with, or slightly antecedent to the natural (unconditioned) stimulus. The smell of the food and the sight of the food occur repeatedly along with the presence of the food in the mouth, and all phases of the feeding event become intermingled as undistinguishable parts of the total feeding situation. A part thereafter may act as a sign of the whole. This theory, then, Pavlov proceeded to test. Supposing a bell were rung just before feeding the dog, and this were repeated many times, would the arbitrary stimulus (dinner bell) become thereafter by itself an adequate stimulus to start salivation? The answer turned out to be positive. The dog did salivate at the ringing of the bell. Now surely one is well started in the use of technique well adapted for the objective, scientific study of digestive behavior, including factors which are psychological in character. For when a puppy, as a result of learning, has reached the point where he sniffs different objects, rejects the stone and snaps up the bone, is not his behavior at least in part psychological? Hence Pavlov became enthusiastic as to the possibilities of studying psychological phenomena as well as physiological behavior by the use of his newly developed technique.

To be sure, the general principle involved was not new. From Aristotle down, students of psychology have expatiated upon the principle of association. It had long been known even to psychologists that if one rings a dinner bell habitually just previous to the presentation of an appetizing dinner, the subject is likely to learn to associate the one with the other and to respond to the sound of the bell, a purely arbitrary stimulus to be sure, by coming to dinner with his mouth watering. This new technique, however, gave promise of revealing the operation of factors far more precisely than before, by more adequate control of both stimuli and responses, so that the learning process might be revealed with greater certainty and in greater detail. In the hands of Pavlov and his associates, who gave note to the dog as well as to the stimuli presented to him, the technique of conditioning has been productive of excellent results.

What, then, are the net gains to be derived from the use of this new technique as applied to human learning? Much depends upon one's definition of conditioning, if he insists that all learning is conditioning. In the hands of the ultra-scientific behaviorists, as we shall see later, it has been trimmed down to mean formation of a new S–R connection such as bell-salivation, by repeated presentation of the arbitrary stimulus (bell), just before, or simultaneous with, a naturally adequate stimulus (food). In this interpretation consideration is restricted to the stimulus and the response, with no reference to the condition of the organism, the mental state of the learner or the effect of the response upon the mental state. *Objectivity is secured not by adding to the objective data, but by discarding all subjective data.* It is as though a physician were to say to a patient entering his office after swallowing a dose of poison: "Now don't try to influence me in my diagnosis by anything subjective. I am much too scientific to be influenced by any so-called ideas you may think you have in what used to be thought of as your mind. I depend exclusively upon objective evidence. I x-ray your bones, record graphically the behavior of your heart, etc., etc., and by the day after to-morrow I shall even have a chemical analysis of the contents of your stomach!"

With regard to consciousness, it is apparent that salivation is a simple physiological response more or less independent of conscious control. One does not turn the salivary secretion on or off as he is presumed to turn the water in the bath

tub on or off at will, In the case, then, of the dog which learns to salivate at the sound of the dinner bell, is the learning of the purely physiological sort and, as such, quite independent of consciousness? The mechanistic psychologist answers in the affirmative.

III

The founder of mechanistic behaviorism was a young man with the wanderlust who had become discontented in the old psychological homestead. As he saw it he was expected to use two very different tools in his work. He found himself saddled with the old introspective tool so elaborately specialized in the hands of Titchener, that tyrannical master trained in the land of the Hitler clan. This tool was used in part in the laboratories carrying on the experimental psychology characteristic of the period.

His first find, which was enthusiastically used, was the S–R tool recently forged by Thorndike. This seemed to be the only usable instrument available about the year 1906 for work in the newly plowed field of animal psychology. Cattell, Thorndike, Bryan and Harter in America, Binet in France, Ebbinghaus in Germany and a large number of others in different countries had demonstrated how subjective and objective methods might be used harmoniously and to the great advantage of results to be gained by each. And they had developed a psychology that was as objective as one well could wish—without throwing out the baby with the bath. However, the second great find of the youthful adventurer was the C–R formula of Pavlov. It was a major invention of the enterprising experimenter to gather it in and trim it to the needs of a brand-new psychology. Not only was the S–R formula of Thorndike to be radically changed to that of C–R, but other changes even more profound were in store for the new science-to-be. For one thing it appeared that the C–R formula, having to do with physiological reflexes, such as salivation in Pavlov's dog, could be considered without inquiring into the animal's consciousness at all. Why not, then, discard consideration of consciousness altogether, discard the subjective element and by reason of this discard have a new science as objective and scientific as physics or chemistry? Great is the promise of the discard! For all one had to do to get the response to the substitute stimulus was to present said stimulus just before feeding the dog. What comfortable learning for the schoolboy! The stimulus takes care of the learning, and the boy doesn't need to know what is going on or even to be conscious at all.

The general statement of the fundamental law of all learning in terms of conditioning is that when a new stimulus (bell) is presented along with or immediately preceding the unconditioned stimulus (food), a new S–R connection is formed. After a sufficient number of repetitions the sound of the bell will by itself call forth the flow of saliva. It would seem to be like the case of school learning in which by simultaneous presentation with repetitions, the stimulus *Columbus* has come to call forth the response *1492*. Yet there is a disconcerting discrepancy between the two sets of data. If the bell is rung many times by itself after the connection *bell-salivation* has been formed, the connection is weakened rapidly and soon disappears. Does this mean that exercise of a new connection weakens it instead of strengthening it? This appears to be in exact contradiction to the fundamental law of exercise accepted by mechanistic psychologists as the sole factor which accounts for establishing a connection. The elementary teacher would surely be disconcerted if she were informed that she must on no account have the learner repeat the stimulus *Columbus,* if she wishes to establish the newly formed connection *Columbus—1492,* since by doing so she would surely eliminate the connection

she has just taken pains to establish. The matter is intelligible, however, if one takes into consideration the *effect* of the response. The teacher is not afraid of repeating the stimulus 3×4 in order to get it well connected with the response 12, provided that response gives a satisfying effect. But if upon repeated trials the ringing of the dinner bell no longer turns out to be a true signal of satisfying food, why should one continue to respond as if it were a sign of food? Surely that would be stupid behavior. When one learns that the bell signal no longer means food, he had better cease salivating and find out what it does signify. What could be more stupid than to keep on acting irrespective of the effect of his action? It is worthy of special note that in the attempt to frame laws of learning to the exclusion of all consciousness, the essential factors of all learning, namely, the readiness of the organism for the response and the effect of the action upon further response, are entirely omitted. Is human learning to be considered without reference to either its purpose or its results?

In view of such considerations, then, is one to harbor a degree of confidence in these "laws" somewhat comparable to that heretofore reposed in the Newtonian laws of motion, because they are presumed to be founded upon evidence which is objective to a like degree? Or do such formulations rather illustrate the difficulties in which one finds himself entangled when he tries to exclude the mental from a study of human life? The behaviorist may well take a lesson from Pavlov on this point. Was it merely a youthful lapse of consciousness to overlook the fact that Pavlov's dog had to be alert—a sleepy dog would not do—and also *ready* with a hunger drive if the learning was to take place? Alertness and motivation would seem to indicate consciousness. Or was consciousness consciously and maliciously done away with to make it possible to trim Pavlov's formula to fit the needs of the new inventions now in prospect?

The brave adventurer was a bit cautious at first in dealing with the matter of consciousness. He tried merely ignoring the troublesome thing. Then, since fortune favors the brave, he decided to deny that there is such a thing and see what happened. Fortune still favored the brave, but things hadn't yet reached the final stage.

Next came the great invention. It was no less than this, to wit, that the only objective, scientific, dependable psychology began in 1912 "when the behaviorist first raised his head," and that all other psychology, past, present or future, must be forever thrown into the discard. This is one of the greatest—probably *the* greatest—of the psychological inventions of the present century if not of all time. One could thereafter look down from the dizzy heights and see the glories of a new era. As stated in one of the leading London papers in reviewing the new book on "Behaviorism":

> He claims to put forward not only a new psychology, not merely a new body of psychological theory, but a system which will in his opinion revolutionize ethics, religion, psycho-analysis—in fact all the mental and moral sciences.

A New York paper comments: "One stands for an instant blinded by a great hope."

Presumably the conclusions arrived at by the new (?) technique of experimentation are to be counted upon as nothing short of the final unadulterated truth. Why bother with speculative philosophy any more?

The behaviorist at length summoned up enough bravado to try a denial of consciousness altogether and stand by for a moment to see what would happen. Nothing happened, except that the new doctrine was accepted and taught to many students in college classes. Those accepting the new doctrine boldly assaulted consciousness at opportune mo-

ments, and built up barricades as best they could to withstand counter attacks upon unconsciousness. But having undertaken to oust consciousness, the trouble was that all the near relatives of that elusive body had to be ejected too. One can't very well banish consciousness and still harbor insight, understanding, purposes, incentives, emotional states of mind and last but not least, the *effect* of past behavior upon future responses. This left only the monotonous law of exercise, the drudge of the classic trio. But it was the only thing to do. Surgery has its place, and sometimes one must pay no heed to where or how much it hurts. To be sure, this makes a sorry plight for the little red schoolhouse with its serious old-fashioned attempt to secure practical purposive results. For, in school, understanding is considered essential, and also the readiness of the learner through adequate motivation. The teacher attempts to control the process by reason of the effects produced. Imagine teaching arithmetic with no life activity to motivate the learning and no resulting satisfaction as the effect of its successful completion.

And so the final stage, mechanistic behaviorism, was finally reached by a series of assaults, consolidations and retreats. For, like Caesar in his Gallic wars, the behaviorist sometimes found it expedient to betake himself as speedily as possible to the fortifications of camp. For example, at one stage it appeared that the ousting of consciousness and of the method of introspection necessitated the exclusion of all verbal report. But it was finally decided that verbal report was too valuable an ally to be dispensed with. Accordingly verbal report was retained as being essentially behavior, and free from any trace of consciousness, insight or effect upon conduct!

Taking a new citadel is like taking on a new line of in-laws or grabbing a bear by the tail. One never knows what it is going to get him in for. However, one has to make at least some show of loyalty and consistency. The behaviorists must surely be given credit for one thing. They have shown good old bulldog tenacity in defense of the unfortunate allies which they got themselves jockied into defending. One just can not but admire their hardihood and their persistence. Some of them, to be sure, rather soon saw the hopelessness of their new positions and scattered somewhat, without appearing to beat too precipitous a retreat. Many of them found purposive behavior too precious to be abandoned. Rugged fundamentalists the pure mechanists assuredly have proved themselves to be. They have discarded the upper story and, in fact, everything above the rock-bottom foundations. The positions still maintained may be enumerated tentatively and in part as follows:

(1) Denial of consciousness and exclusion of all its implications. "Belief in the existence of consciousness goes back to the ancient days of superstition and magic."

(2) Consequent exclusion of the introspective method, in which the experimenter admits for evaluation the *testimony* of the subject. The behaviorist on the contrary records and interprets the *verbal report* of the subject, since this is behavior.

(3) Denial of motivation or *readiness* of the organism as having any bearing upon the response that is made by it, and affirmation that it is the stimulus which is responsible for the action which ensues.

(4) Consequent denial of the *effect* of an action as having anything to do with influencing future actions.

(5) Denial of everything mental, and consequent affirmation that man is a physical mechanism without consciousness—a robot—whose actions are inevitably and absolutely determined by the stimuli with which he happens to be confronted, and by the conditioning that resulted from the influence of stimuli with which he has been confronted previously.

IV

What, then, shall one say of the central theme under consideration, that consciousness, mind, human experience are mere delusions and that human life is the rôle of a mechanistic robot? What

are the alternative views? One is the vitalistic theory, that there is something in man independent of his physical organism, which accounts for his "spontaneous" acts, his "self-activity" or "free will" or whatever one cares to call it. This sounds like an assumption of the immaterial soul of a really bygone pre-scientific age, long since abandoned by scientific workers. Strange to say, the mechanistic psychologists would appear to believe that this is the only alternative to the acceptance of their "scientific" view. But is it? Is one conscious now as he reads this page? A professor not infrequently has in his lecture room a few persons with sufficient confidence in the orthodoxy of what is likely to be said, to be willing to drop off into unconsciousness and leave the lecturer a free field. But in that case the professor has been known to be so revengeful as to put the points learned while asleep on the next written test. This is very likely to confirm the view that consciousness has something to do with learning. One may be willing to admit that he has never experienced the consciousness of any one but himself, and nevertheless be most assuredly aware of his own consciousness. Also, by inference he may believe it extremely probable that most other people have consciousness—of a sort—as well as he. They act as though they did. It is difficult or impossible to find a substitute explanation of their behavior which fits the facts as well as the theory that they are conscious persons too.

As for the other facts and inferences of the physical sciences which seem so sure to the mechanists, one could never learn them, understand them or even think of them if he were unconscious at the time. Is not one's consciousness, one's state of mind, the one and only thing that can be known directly? Everything else is inference dependent upon this primeval phenomenon.

If, then, the fact of consciousness be accepted as a reality, and the physical world including man be also accepted as a reality, do we not have on our hands the age-old mind-body problem? If man is a physical organism responding to physical stimuli, how can he also be a free agent with a mind? One is tempted to dodge the issue, of course. But it is not a satisfactory means of escape from a tiger to shut one's eyes to the tiger. When one sees the burglar entering the bedroom, he may call it an illusory dream if he wants to, and prove it by quoting the mechanistic experts who are sure that all consciousness is a delusion—if indeed there is such a phenomenon at all. But that proof is of little value next morning when one's partner finds the jewelry missing. And for that matter even the hard-headed scientist turns practical philosopher in his off-guard moments when he is a mere man instead of a scientist. He adopts the theory and the behavior that work best to save the jewelry, scientific theory to the contrary notwithstanding. And it would appear that this practical behavior of the uncouth anthropos is by some chance not out of harmony with the modern mode in philosophy called pragmatism. Maybe one shouldn't let trade secrets out of the bag. A doctor must write his prescription in Latin, you know. But at any rate when translated from philosophical jargon into English the root idea of pragmatic philosophy seems to be that the truth of a theory is tested by how well it works. In the case of the burglar incident, doubtless many an individual will continue to take his consciousness of the presence of the burglar seriously, and also the consciousness of those nearest and dearest to him, as to the loss of the jewelry.

In any case it is fortunate for man in the raw that this is a democratic country and that it is the majority vote that carries the day. However, the majority

will have no objection to the mechanist playing his little game all by himself with his consciousness submerged or repressed, though that would seem to us crude folk to be a psychological depression worse than the recent economic one.

But to return to the point at issue—to be conscious or not to be conscious: that is the question. Whether it is smarter in the fight for fame to face things as they are in the hard practical world—to take arms against a sea of problems and by reflection solve them. Why not lose consciousness in peaceful sleep? To sleep! And by a sleep to say we end the head-aches and the thousand awkward knots psychology is heir to. 'Tis a consummation devoutly to be wished. But in that sleep of peace what nightmare might emerge! Ay, there's the rub should give us pause, and bid us rather face the facts we have than fly to tangles that we know not of.

Consistency makes drudges of us all. And oft the resolution pales. But hist! What fine invention's this! I'll change the name of action and call it pure behavior! I'll be the first behaviorist and start another *ism!*

Now Fortune's headed rough
And damned be he who first dares call my bluff!

V

Seeing that some one must take up the psychologist's burden, how shall one account for consciousness? Surely not in terms of a resident vitalistic principle, alias immaterial soul. That would raise the still more disturbing nightmare as to where it exists, what sort of thing it is, and how it could harmonize with the fact that the nervous system and body as a whole correlate so closely with the individuality of the person, with the functioning one finds it so convenient to designate as mind. There surely is no evidence of mind apart from a functioning nervous system. Mind and brain are phases of the same reality. One may lose a leg and substitute a wooden leg for it without seriously interfering with the quality of his intellect. But it is a different story if anything seriously disturbing happens to the nervous system. A wooden head, unless obtained by inheritance, does not work at all. Even when inherited it is nothing to brag about. May one not be on speaking terms with both a brain and consciousness?

Again, who is to give one the final word as to just what electricity is and what it is not? Is it the shock one receives when he comes within a circuit? Is it a flash of light? Is it a form of energy? Or should one consider only the physical structure, the dynamo, and some one phase of its "physical behavior" and deny the reality of all other "apparent" manifestations? May it not be that one form of manifestation has as much claim to reality as another, provided consideration of it may prove useful in a life situation?

As to mind, consciousness, human experience, these seem most appropriately considered as aspects of a functioning nervous system in a living organism, just as an electric current is aptly interpreted as a part or phase of the functioning of an electric dynamo. Why deny either the current or the dynamo or the power by which the electric train is propelled? And in psychology what is to be gained by denying mind or consciousness? Let those who wish specialize on this aspect of behavior, while others concentrate on the physical aspects of behavior, such as the action of muscles and glands. Every man to his trade. Live and let live. There is no call for warfare. It is unnecessary to assume that all physical structures must function in the same way.

As to whether there can be any such thing as spontaneity of action, any degree of choice or volition, I quote from Gerard:

Evidence now on hand has established the fact that the nerve itself generates or actively propagates the impulse, as a fuse passes on a spark. The nerve is active, not passive. In the same way the central nervous system must now be looked upon as composed of active units continually in play and which are modified rather than set in motion by particular types of stimuli.[1]

This affords a physiological basis for Froebel's assumption of self-activity on the part of the child, a concept which seemed to add greatly to the vitality of the educational philosophy of his time. How about the activity of the heart? That beats incessantly from before birth to the end of the three-score-and-ten period. But this action is not credited with being under voluntary control. It exemplifies physiological activity rather than mental activity. Its center of control is beneath the functional center of the organism as a whole, topographically as well as functionally.

How about breathing? One can take a deep breath "voluntarily," but one can not commit suicide by holding his breath. Breathing is not under voluntary control to that extent. How about running a hundred yards in ten seconds or writing a scientific treatise on geology? The sprinting is well within the range of freedom of an organism such as that of a Jesse Owens, but beyond that of most of us. Similarly with regard to writing the treatise on geology. Such functioning is forever beyond the bounds of volition of an idiot. In the case of certain persons it could become possible with sufficient training. In any case it appears that the bounds of "volition" and "choice" are decidedly restricted. No scientist of today would defend a large degree of human freedom.

But there is no philosophic problem of more far-reaching significance than that as to whether there is at least some small degree of human freedom, as opposed to one hundred per cent. mechanistic determinism. With little or no determinism there could be no stability, no prediction, no science. All would be chaos. On the other hand, if there were absolute mechanistic determinism there could be no such thing as human responsibility, and therefore no significance in human life.

What part of the organism is responsible for the voluntary aspect of behavior, if such there be? A common answer characteristic of the gestalt school is that one thinks with his whole body. But this statement is likely to be misleading. One who has just broken his leg thinks *of* his leg but not *with* his leg. To quote again from Gerard:

The nerve cells, then, can spontaneously discharge impulses but normally do not do so because they are dominated by a more active region. . . . Even at "rest" there is an active equilibrium—some cells discharging, some beating electrically, others held quiet; by the play upon them of nerve impulses, field potentials, blood chemicals and other still unknown means of integration. . . . Such a dynamic concept of activity of the nervous system gives us also a possibility of explaining other phenomena, now well established, but inexplicable along more orthodox lines. Some of these are: *the unitary stream of consciousness*. . . .

VI

Finally a word is called for as to that most outlandish of all claims of the extreme mechanist, that the *effect* of an act has no influence upon future acts. If experimental evidence is desired on this point, one may consult the recent publications of the Institute of Educational Research of Teachers College, New York City. It is a poor fish that must keep on forever biting the same hook that gives him nothing but a pain, assuming that

Lacking the sense to run away,
He lives to bite another day.

Surely the mechanists do not mean to slam *homo sapiens* so severely as this. Sometimes, to be sure, there is evidence of stupidity a-plenty, but on the other hand there are also indications of intelli-

[1] R. W. Gerard, SCIENTIFIC MONTHLY, January, 1937, p. 51.

gence, of profiting from the effects of past experience.

What is it that scientists are really after in their supposed search for truth? Is it not essentially the *consequences* of the various factors under consideration? What, for example, are the *effects* of exposure to the typhoid bacillus, the effects of vaccination? Effects, relationships, consequences—these seem to be the goals of the search for truth. And it is the truth that gives one that degree of freedom and control which it is possible to achieve. Freedom is a matter of ability to avoid certain effects and to substitute other effects, made possible through knowledge of relationships between factors and their effects. Professor John Dewey has emphasized the need of regard for consequences. To disregard effects, consequences, surely this is the behavior of an undisciplined child. Only the foolish, the witless, the thoughtless, disregard the consequences. Foresight implies prediction of probable after-effects, and foresight is the part of wisdom as opposed to folly.

Some may consider it unjustifiable to bring the philosopher into the discussion. Is the scientist right when he gives vent to the belief that the philosopher is only a speculator, a brain-truster, not one who by use of the modern methods of research arrives at the final truth? Scientific methods should yield reliable truth, but unreliable people will play with scientific methods. Philosophers, too, continue to survive, and Darwin, who was something of a scientist in his day, considered that survival was to the credit of the survivor, in that it had something to do with fitness.

But what is the difference between the scientist and the philosopher? Both profess to be in search of truth. In general, is it not the function of the philosopher to look at things in the large? He does not detach things from their connections. He emphasizes relativity, relationships, synthesis. He strives to take in the whole, fit all the parts together with none of the parts left out, and each part fitted into its appropriate place so as to make a consistent whole. If he were in an automobile plant, he would be an assembly man. Such work is surely important, for what does it profit a man to know all about a carburetor if there is no one to fit the carburetor into its place so that the car will go?

And what is the special function of the scientist? Is he not for the most part a specialist on parts? The behaviorist, for example, specializes on the more specific forms of behavior, such as reflex responses. Sometimes one is tempted to remind him that possibly the best salivator may not turn out to be the keenest intellect, or that the behavior of rats in a maze may at times be somewhat different from that of humans in a fog. Also one is tempted to remind him that it is not always wise to be too dictatorial even if one has absolute confidence that the principle upon which he is depending is correct. One is reminded of the motorist who went straight ahead, oblivious to all other considerations, because he was sure that he had the right of way. He arrived at his final destination many years ahead of time, and is still oblivious to all irrelevant points of view, even including his precious right of way!

Is it safe to depend exclusively upon one point of view? Is it safe to consider the part and be oblivious to its relation to the whole? Is not this the part of narrowness and the particular sin one is prone to charge up to the account of the fundamentalist? It is no easy task to try to see all the parts in their relation to the whole, but such is the goal of the philosopher; and philosophy, synthesis, appreciation of significant broad relationships must be a part of every science which would hope to apply its contributions to the life of man as a whole. There are, moreover, trade demarkations. A psychologist may respect the field and func-

tion of the philosopher without muscling in on his territory or excluding him from the union. The analyst had best learn to work in harmony with the synthesist or else agree to stick to his own trade.

VII

As a means to this end, it would seem that the prodigal had now gone far enough to see the error of his ways and that he should be almost ready to return to the old homestead. He struck off when quite young, with a laudable ambition to explore the world without the restricting influences of his elders. So far, so good. But he fell upon evil times. First he lost his mind, as earlier historians have recorded. "Then he lost consciousness, but still retained behavior—of a sort." The behavior, however, was by no means adequate, being confined mostly to the cruder reflexes and the like. In short, the organism was largely defunct. It responded to nothing but external stimuli and was paralyzed from the neck up. Having lost consciousness, the poor fellow was seriously disoriented. He had become entirely oblivious to the complexity of normal human behavior and of the many factors accounting for it, such as the readiness of the organism, the constitutional differences in organisms from the outset, the subleties of the configurations in which the stimuli might have their settings, the effects of past behavior and such like.

These symptoms will doubtless suggest the diagnosis as that of advanced paresis, though occasional flashes of involuntary insight and of detached emotional responses might seem to cloud the picture somewhat and rather to suggest dementia praecox, especially in view of the youth of the victim at the initial stages of the onset of the disorder.

Be that as it may, it is surely high time for the prodigal to come home. He will be welcomed back to the family fireside. The effects will be most satisfying to all concerned. One hesitates to mention the matter of conditions of his return. The home can well afford to be magnanimous. There will surely be more freedom than in the unbelievably restricted sphere of action depicted above. Of course the veil had to be drawn over certain details. But it is to be hoped that the son and partial heir will not in future ignore the *effects* and consequences of his behavior, nor ever again pawn or discard his mind, which is believed by many to be one of the most valuable possessions bequeathed by inheritance from a long line of ancestors. And also it is to be hoped that, if there ever should hereafter be a temporary lapse from the path of rectitude, it would turn out to be only a temporary debauch falling far short of a total loss of consciousness with all the dangers which this loss implies. These admonitions are intended in all kindness. They are the outcome of the wisdom of the ages of psychological accumulation from Aristotle down.

The return might be suitably celebrated by killing the emotional complexes that have tended to block the free scope of the intellect. The freedom thereby enhanced would surely contribute to peace and prosperity for all members of the psychological family, now grown so large and so divergent in family traits.

The return might change the mode of thinking somewhat for a few, but then the modes change anyway, as there has been occasion to note, from causes not wholly logical even in matters believed to be quite highly intellectual. Peace without victory! How may this be secured? Surely this is one of the great unsolved psychological problems. It deserves consideration in the not too distant future.

HOW WE SPEND OUR TIME AND WHAT WE SPEND IT FOR

By EDWARD L. THORNDIKE

INSTITUTE OF EDUCATIONAL RESEARCH, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

I HAVE been at some pains to collect available statistics on how people now and in times past have spent their time. The results are rather meager. Indeed it is not certain that my estimates for men and women of this country are more accurate than those which Dr. Nissen made at my request for chimpanzees! He writes:

> There is probably considerable variability in how a chimpanzee spends the day in his native habitat. Especially important is the age of the animal; sex, season, composition of the group, geographical locality and food supply, I think are also factors. My estimates, which in part at least are pretty wild guesses, are based largely on experiences during the dry season in French Guinea.

	Adolescent	Adult
Sleep (in a nest at night)	11 hours	11 hours
Resting (on ground during day)	2 "	4 or 5 "
Eating activities (includes climbing around in trees, picking fruit, peeling and shelling; intermittent rest) Productive labor (travelling towards sources of food, water, nesting sites, avoidance of enemies; building nests)	6 "	6 "
Social and individual play, fighting, sex courtship, auto- and hetero-grooming	5 "	3 or 2 "

> A very different distribution would be found for nursing mothers.

There are a number of reports concerning the time schedules of students, but their case is too special to use except as a supplement. The best data concerning adults are those given under fifty-nine rubrics by Nelson[1] for a large group (nearly 500) connected with a Y. W. C. A. The study made in 1931 was repeated in 1932. From Nelson's records I compute that 48 hours a week are used to get a living (including time of transportation to and from work), 56 hours for sleep and 3½ hours for responsibilities to the home where one lives. Twenty-four hours are spent in eating, personal care and shopping. The remaining 36½ hours include: church activities, 1½; outdoor games and sports, 3¼; automobile rides and trips, 4½; reading, including the newspaper, 7; studies and lectures, 1–; movies, theater, pageants, 3¾; sedentary games, 1¾; music, 1¾ (seven eighths of which is passive listening); radio other than music, 1–; sewing, painting, arts and crafts, 1–; parties, dances, picnics, club activities, dates with men and entertaining in the home, 9.

We may summarize the expenditures of waking hours as 48 to productive labor, 6 or less to other duties, 33½ or more to pleasure, 24 to eating, personal care and shopping, and ½ unspecified. If the 24 hours are credited half to keeping the person alive, well and presentable for her work and half to the pleasures of the palate, of sociability and of gaining the approval of others and of oneself by one's appearance, the total for work and duties is 66, not quite three fifths of waking time; and that for pleasure is 45½+, somewhat over two fifths. Of course, some of the productive labor and going to and from it may be pleasurable also.

Moralists generally, and the liberal reformers of the nineteenth century in

[1] "Leisure-Time Intervals and Activities of Business Girls," 1934.

particular, seem to have expected that if people were enabled to obtain the necessities of life with a part of their time and energy, they would use a large fraction of the balance in the pursuit of learning, wisdom, beauty and good works. The fraction is small in these business girls. Except for the newspaper, the average reading is about 3½ hours a week, studies and lectures are less than 1 hour, and even an optimistic evaluation of the concerts, club activities, etc., would probably not sum to an hour that would have been approved by Bentham or either Mill (or for that matter, by Carlyle or Ruskin or Matthew Arnold or Cardinal Newman). Yet this group is probably much superior to the average of the population and had convenient and free access (in New York City) to science, literature and art. They had the time and were obviously not exhausted by their labors, since they resorted to resting other than sleep for less than one hour per week.

A benevolent and intelligent trustee for the welfare of these young women should move rather cautiously in the direction of increasing the amount of their pure pleasure time. It may be better for them and for all concerned (1) to improve the health of the individuals, (2) to improve the quality of the home so that the 40 odd hours spent there in eating, dressing, reading and housework are more enjoyable, and (3) to improve the quality of the office or shop so that the 42 hours spent in productive labor are more enjoyable.

Before commenting further on the facts, let us try to translate the schedule of time spent (except in sleep or at productive labor for a wage) into a schedule of wants gratified. For example, how should the hour and a half spent in church activities be allotted among the desires for security, for the approval of others, for self-approval, for the welfare of others, for mental activity, for social entertainment and for the pleasures of sight and sound? How should the 10

TABLE 1

THE PERCENTAGES OF THE TIME SPENT IN VARIOUS ITEMS OF ACTIVITY BY BUSINESS GIRLS WHICH GRATIFIED CERTAIN WANTS, ACCORDING TO A JURY OF PSYCHOLOGISTS

	Personal care	Home responsibilities	Automobile	Talking with family	Writing letters	Reading the newspaper	Church activities	Sum for 55 items, all except sleep, work, and transportation to and from work
1. Protection against hunger, cold, heat and wet, animals, diseases, and bad people, exercise, rest and sex relief	10.8	15.5	9.7		0.1	4.0	4.0	20.2
2. Avoidance or reduction of pain	3.2	1.9	3.0		0.1	0.8	1.1	2.1
3. Pleasures of taste, smell, sight and sound	5.8	10.5	16.1	2.8		8.3	6.9	14.3
4. Mental activity, curiosity and exploration		0.3	6.7	5.9	11.6	58.3	3.6	8.1
5. Manipulation and construction	0.8		1.6		0.1			1.0
6. Security (other than in 1)	3.8	10.5	0.3	9.3	4.7	1.7	17.4	1.5
7. Affection (to get it)	14.1	3.7	3.5	14.8	15.1		3.6	4.7
8. Companionship	5.3	4.1	12.6	29.6	18.3	5.8	16.7	8.5
9. Approval from others	19.6	16.3	3.5	2.8	11.1	2.5	7.3	7.3
10. Approval from one's self	14.2	9.2	0.3	1.9	5.3	5.8	5.8	4.3
11. Mastery over others	5.3	1.7	0.8	3.7	3.3	0.8	1.1	1.9
12. The welfare of others	0.5	10.2	0.8	9.3	9.7	1.7	7.3	1.9
13. Sex entertainment	11.4	8.5	15.9	0.9	16.7	2.5	5.8	11.5
14. Social entertainment	3.0	6.1	24.2	17.6	3.5	3.3	16.7	10.5
15. Physical entertainment	1.1	0.7	0.8		0.1			1.5
16. Unspecified comfort	0.8	0.7	0.3	0.9		4.2	2.9	0.7

hours for personal care be allotted? How should the $3\frac{1}{2}$ hours for home responsibilities be allotted?

Table 1 shows the allotments in the case of samples from the 55 items according to a jury of six psychologists and also the summation of the allotments of all the 55 items reporting time spent other than in sleep, work for wages and transportation to and from work.

In so far as the jury's allotments are dependable, the time other than that spent in sleep, work for a wage, and transportation to and from work serves chiefly the desire for entertainment in a broad sense. Including the allotments to sensory pleasures of taste, smell, sight and sound, and half of those to mental activity, curiosity, exploration, manipulation and construction, 42 per cent. of such time is so spent, about 20 per cent. being spent for physical needs, about 12 per cent. being spent to get approval and about 13 per cent. to get companionship and affection. The results by any reasonable allotments would not differ greatly from these.

Records like these from business girls are not available for business men, farmers, factory workers, housewives or any large adult groups. We have to rely on general observation helped out by various facts of record.

The hours of sleep for adults 20 to 60 may be set at 8 per day or a bit more. The amount of mere rest (*i.e.*, rest without any accompanying entertainment) is probably under half an hour per day. In the business girls it was an eighth of an hour. In reports by professional, sales and factory workers (male and female) of a telephone company, less than 2 per cent. of leisure time was credited to mere rest. The amounts would presumably be larger for persons doing hard muscular work, but they are a small and declining minority; and few even among them are too tired to enjoy the radio.

In ordinary economic conditions the average number of hours of work for wages or about the home, including time spent in going to and from work, is probably not far from 50 per week or 7 per day for adult men and women. The variation is of course enormous, probably from zero to a hundred, as suggested by Masters's poem.

In the hives of all the cities, high above
The smoke and noise, where the air is pure,
Are numberless widows, comfortable and secure,
Protected by the watchman and God's love;
Saved by the Church, and by the lawyer served,
And by the actor, dancer, novelist amused.
Some practise poetry; some, who are younger nerved,
Dabble in sculpture; but all are used
To win the attention of celebrities
At dinners, or at the opera, to imbibe
The high vitality of purchased devotees.
But when not modeling, or scribbling verse,
Nor drinking tea, nor tottering forth to dine,
They sit concocting some new bribe
To life for soul relief; they count what's in their purse;
They stare the window half asleep from wine
Or poppy juice; they wait the luncheon hour;

. . . .

And in the city there are numberless women,
Widows grown old and lame, who scrub, or wait
On entrance doors, or cook; whose lonely fate
Is part of the city's pageant, part of the human
Necessity, victims of profligate
Or unprevisioned life! They have no spoil,
No dividends, and no power of subsidy
Over the world of care and poverty;
They have but patience and a little room,
Patience and the withered hands of toil.[2]

The farmer's work is a balance of the seasons; the soft-coal miners have tried for years to get 200 days of work per year; the retail dealer and his clerks may work far beyond union hours; many houseworkers add the care of their own homes to eight or more hours for wages. But these great variations are consistent with even greater uniformities. In ordinary times most workers in factories, retail and wholesale stores, railroad and utility companies, schools, the civil ser-

[2] Edgar Lee Masters, "Poems of People," D. Appleton-Century Co., N. Y., 1936; pp. 120, 121, 122 (Widows).

vices, banks, insurance companies, hotels, restaurants and households have regular jobs with regular hours of work and regular duties at home, summing, as stated, to nearly fifty per week.

The care of the body and personal appearance may be estimated at 5 hours a week for men and 8 for women. Routine eating takes perhaps 10 for men and 8 for women (the difference in time being spent by the women in serving and cleaning up, counted in their work records).

About 40 hours a week are left at the adult's disposal. He is free to use these to gratify any of our wants—for security, affection, companionship, approval (of himself, his fellow-men, or his God), power over things or people, the welfare of others, intellectual activity and achievement or entertainment of whatever sort we choose. I shall make a provisional estimate of how they are used by allotting the schedules of leisure time activities reported by professional, sales, and factory employees of a large telephone company to the wants they seem to serve. I shall be guided by the judgments of a jury of psychologists.

For example, games, sports and other forms of exercise (including sailing, hunting and fishing, but excluding gardening) account for 12.8 per cent., 16 per cent., and 21 per cent. of the leisure time reported by professional, sales and factory men, and for 7.6 per cent., 9.3 per cent. and 21.8 per cent. of that reported by professional, sales and factory women, respectively. I allot time so spent as follows:

to the desire for physical, and also sensory, intellectual, sex and social entertainment	76 per cent.
to the desire for companionship	10 " "
to the desire for approval	6 " "
to other wants	8 " "

Playing cards and other sedentary games account for 7.6 per cent., 4.6 per cent., 4.5 per cent., 5.2 per cent., 5.6 per cent. and 2.7 per cent. in six groups, in the order MP, MS, MT, WP, WS and WF (M = men, W = women, P = professional, S = sales, F = factory). I allot 65 per cent. to entertainment of all sorts, 15 per cent. to companionship, 8 per cent. to approval, 5 per cent. to the enjoyment of power and 7 per cent. to all other wants.

Parties, dancing, conversation and other social gatherings account for 5.5 per cent., 13.4 per cent., 8.2 per cent., 13.3 per cent., 11.4 per cent. and 12.7 per cent. in the six groups. I allot 60 per cent. to entertainment, 25 per cent. to companionship, 5 per cent. to affection, 5 per cent. to approval and 5 per cent. to all other.

The radio, movies, talkies, theater and vaudeville account for 7.2 per cent., 23.3 per cent., 18.5 per cent., 10.4 per cent., 23.1 per cent. and 17.2 per cent. of the time reported by MP, MS, MF, WP, WS and WF, respectively. I allot 80 per cent. to entertainment, 10 per cent. to companionship and 10 per cent. to all other wants.

Reading accounts for 32.7 per cent., 31.5 per cent., 19.2 per cent., 35.6 per cent., 31.2 per cent. and 18.3 per cent. in the six groups in order. I allot 60 per cent. to entertainment, 9 per cent. to approval from others, 7 per cent. to self-approval, 20 per cent. to intellectual cravings which are too useful, fine or noble to be rated as the desire for mere pleasure or entertainment and 4 per cent. to all other wants.

So far we have about three quarters of the leisure time of these adults accounted for, with the desire for entertainment far in the lead and the desires for companionship and approval at the head of the others.

I have considered that 70 per cent. of automobiling ministers to entertainment directly or indirectly, and 15 per cent. to companionship, and 15 per cent. to all

other wants.[3] Time spent in making music and listening to music (other than radio) is assigned 80 per cent. to entertainment, 10 per cent. to approval and 10 per cent. to all other. Gardening time is assigned 50 per cent. to entertainment, 20 per cent. to approval, 20 per cent. to the welfare of others and 10 per cent. to all other.

Allotting the times stated by the percentages stated we have the estimates of Table 2.

Evidence of the use of leisure time for the welfare of others is rare, except in the case of the professional men. They report 9.2 per cent. of the time as "with family or children." In the other five groups (in order) this figure is 0 per cent., 2.0 per cent., 1.4 per cent., 1.6 per cent. and 0. The other evidence is in the time spent in clubs more or less concerned with social betterment. The percentages are 3.3, 0.3, 3.4, 4.3, 0.6 and 1.4. The reports for religious activities give 1.7 per cent., 0, 0, 1.5 per cent., 1.6 per cent. and 2.5 per cent. The reports for lectures and studies give 1.4 per cent., 6.3 per cent., 5.0 per cent., 4.4 per cent., 4.3 per cent. and 5.8 per cent. The reports for sewing give 0, 0, 0, 0.5, 1.9 and 8.3 per cent.

Some of the times for family, clubs, church, lectures and studies and sewing should be allotted to entertainment, but we may use this as a factor of safety for the conclusion that over half of the free time of adults in this country, or about 25 hours a week, is spent for entertainment. Another large fraction is spent for companionship, which is itself in part a form of entertainment.

The radio, the talkies, the automobile and the popular magazines are ready providers. They do not, however, completely fill the bill, since, by nature or training or both, people demand companionship, sociability and a chance to talk, and favor a certain amount of physical activity. The family circle and the social gathering are not and probably never will be outmoded as sources of enjoyment (certainly not the latter). They maintain their appeal; a friendly group engaged together without compulsion in almost any sort of activity will entertain itself.

The amount of time spent in physical entertainment by means of games and sports has probably increased also within the past generation. But the enormous increase has been in reading magazines, riding in automobiles, going to the pictures and listening to the radio. The time saved from wage-work and family work by reductions in hours and by gas, electricity, household appliances has gone for increased entertainment, supplied mostly by these four means.

Some students of history and sociology will credit the present flood of entertain-

TABLE 2

ALLOTMENTS OF LEISURE TIME FOR PROFESSIONAL, SALES AND FACTORY EMPLOYEES OF A LARGE COMPANY

	Professional		Sales		Factory	
	Men	Women	Men	Women	Men	Women
Percentage of leisure time reported as spent in games and sports, social gatherings and conversation, radio, theatre, movies and talkies, reading, music, automobiling, and gardening..	76.0	80.9	89.8	85.2	87.2	78.0
Allotted to entertainment	49.2	52.3	61.4	58.3	59.6	54.8
Allotted to companionship	5.0	6.5	9.3	7.2	7.6	7.9
Allotted to approval	8.2	7.7	7.1	6.9	6.9	5.4

[3] If it were the use of money to buy the car instead of the use of time for riding in it, the desire for the approval of others would count heavily.

ment to the great increase in the supply coupled with commercial methods of stimulating the demand. They will argue that men will, under fit environmental conditions, spend their free time in serving the state by fighting or otherwise or in serving the church by religious rites or in serving the family by labor and ceremonial. They will assert that men will follow true gods of truth or beauty or virtue or utility or the common good as readily as the false god of entertainment if they are shown the right path by example and have their feet set upon it by habit.

I hope that this is so. But I fear that the craving for entertainment is deeply rooted in man's nature and that very strong counter-attractions will be required to stem the present flood. I prophesy that historical and anthropological research will increasingly reveal that the great majority of people have spent their free time for entertainment up to or beyond thirty hours a week, if a supply was available. The desire for approval may counteract it widely, as in waves of Puritanism or patriotism. Also, the desire to see others happy, which apparently has been held down by brutal and bigoted customs in most civilizations, may become a more and more potent alternative, at least in superior souls. The human nervous system is very adaptable and can learn to operate with satisfaction in a humdrum world. But its lines of least resistance go toward cheerful sociability, free play, sensory stimulation and emotional excitement.

SOME MEXICAN IDOLOS IN FOLKLORE

By Dr. ELSIE CLEWS PARSONS
NEW YORK, N. Y.

EVER since an English gentleman named Septimus Crow "discovered" Lake Chapala in the state of Jalisco, Mexico, and built its first villa where he entertained German merchants from Guadalajara, American railroad men and Porfirio Diaz, there has been at this little lakeside resort a traffic in the *idolos* which have been washed up from the lake or dug up in the hills back of the town, in ancient Indian cemeteries, or faked by the townspeople. An English lady who visited Chapala thirty-nine years ago quotes Mr. Crow as saying that the *idolos* sold Lumholtz were faked, information that the somewhat malicious Mr. Crow did not impart to the ethnologist. I do not know what Lumholtz did with his collection, but about this time Frederick Starr also made a collection of the miniature pottery water jars, figurines, etc., which came from the waters of the lake, and this collection is in the Peabody Museum at Cambridge. This collection is not faked. Starr published a careful description of the collection,[1] but beyond giving some comparative notes on miniature offerings made elsewhere in Mexico he gives little or no account of the way the Chapala Lake offerings may have been made.

Miniature pottery vessels were offered by the ancient Aztecs,[2] Tlascalans[3] and Zapotecs[4] in their mountain shrines as prayer-images. These miniatures are also being found on Monte Albán so the ancient Mistecans may also have offered prayer-images of this type. Some of the modern Zapotecs, also the Mixe, still offer them, the Zapotecs calling them *pedimentos*, requests, for what they are praying for. The people of Mitla and nearby towns make their "requests" from the stones of the fields New Year's eve when they visit the miraculous cross which probably marks the site of an ancient temple; the mountain people of Yalálag make theirs of pottery and deposit them in a stone shrine on a mountain pass during their pilgrimage on the fourth Friday of Lent. I think the miniatures from Lake Chapala were similar prayer-images.

All the Chapala offerings are either perforated or of a form to which string could be tied. They may have been hung on a stick, a prayer-stick, just as the Huichol Indians hang their miniature prayer-images to-day. The Huichol and Cora who live in the mountains of Nayarit, northwest of Chapala, are reputed to have come from the east, possibly as refugees at the time of the Conquest. They have many traits in common with the Pueblo Indians to the north and with the ancient Aztecs, and among these traits figure prayer-sticks or arrows and miniature ritual objects.

Among the Chapala miniatures are animal figurines, some of an animal I do not identify, others are unmistakably figurines of a dog. The dog figurine that I had on my table at Chapala was plainly a faked one—it had never been under the ground or in the water; but why had the maker modeled the dog just that way, with something in its mouth and some-

[1] "The Little Pottery Objects of Lake Chapala, Mexico," *Bulletin* II, Department of Anthropology, University of Chicago. 1897.

[2] Fray Bernardino de Sahagún, "A History of Ancient Mexico," 134. Tr. by Fanny R. Bandelier. 1932.

[3] F. Starr, "Notes upon the Ethnography of Southern Mexico," *Proceedings of the Davenport Academy of Sciences*, VIII, 117, 1899–1900.

[4] E. C. Parsons, "Mitla, Town of the Souls," Index, Prayer-image. University of Chicago Publications in Anthropology. 1936.

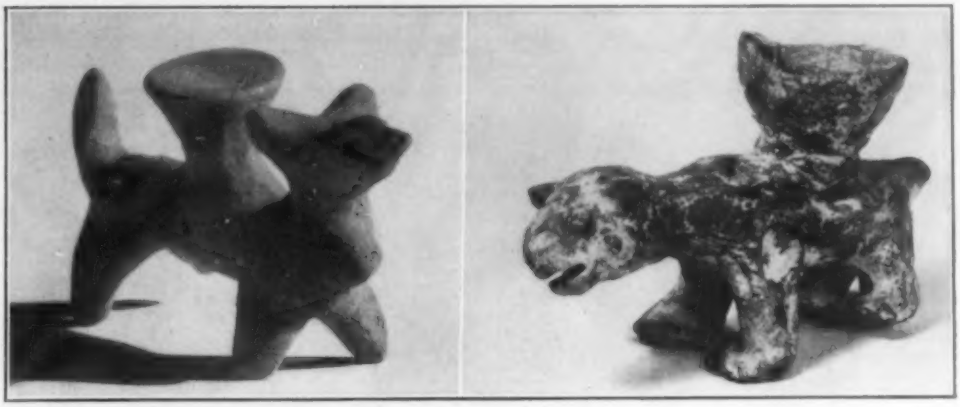


FIG. 1. DOG FIGURINES
Left. FIGURINE FROM CHAPALA, JALISCO. *Right.* FIGURINE FROM CHIAPAS. LENGTH, 5 IN. PEABODY MUSEUM, HARVARD UNIVERSITY.

thing on its back? Nobody knew. Then one day as I was inquiring into the belief about the dog that carries people over the river of death, an ancient and modern belief[5] both among the Aztecs and the Zapotecs, and one that is held also by the Chapala townspeople, the secret of the dog figurine was revealed. The dog is being well fed and he stands ready with a burden basket on his back to swim a passenger across the water (Fig. 1).

The dog ferryman belief is that if you treat dogs well a dog will carry you across the big river you have to cross in your journey after death, a river sometimes identified with the River Jordan, but if

[5] The Lacandones of Chiapas in southern Mexico may have had the same belief, for at each corner of a grave is placed a small palmleaf figure of a dog; and a clay figurine (Fig. 2) collected by Dr. Tozzer ("A Comparative Study of the Mayas and Lacandones," 47, 91, Pl. XIX, Fig. 1), resembles the Chapala figurine.

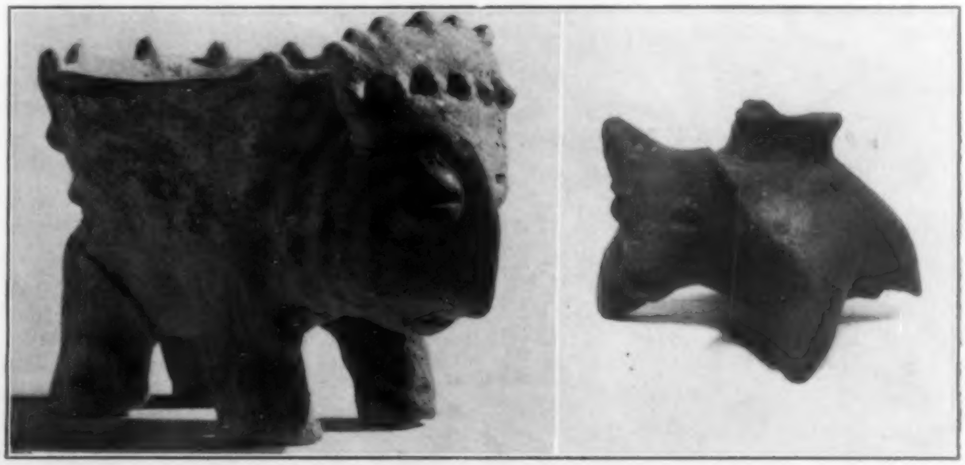


FIG. 2. FIGURINES FROM JALISCO
Left. COLLECTED AT CHAPALA, IN 1934. *Right.* COLLECTED IN 1884. PEABODY MUSEUM.

FIG. 3. TRIPOD
COLLECTED IN CHAPALA. AMERICAN MUSEUM OF NATURAL HISTORY

you have maltreated dogs, beating them or refusing them food, you will be left stranded on the bank of the river. The river dogs are black for an Indian, add the Zapotecs, and white for a Spaniard; white dogs will not carry an Indian lest they soil their coats—unless you have a piece of soap with you and promise to wash your ferryman on the other side. The burden or carrying basket of the Chapala Lake region, the ancient basket carried in the ancient way, by tumpline, is the exact shape of the object on the back of the dog figurine, narrow and deep and flaring toward the top.

FIG. 4. FIGURINE OF HARVESTER
COLLECTED IN CHAPALA. AMERICAN MUSEUM OF NATURAL HISTORY.

In identifying another type of basket I was less fortunate. This is the basket carried by the creature both the ancient and the modern peoples call nagual. Among the Zapotecs and the southern peoples[6] nagual is a kind of guardian spirit secured to a child at birth by sprinkling ashes outside the house and observing the tracks made in the ashes the night of the birth—tracks of lion or of some other animal, of a snake or bird, or marks of lightning. Lightning or Lion becomes the nagual of the child and will aid him throughout life. Among the Tlascalans nagual was a night pilfering spirit,[7] and this is the conception of nagual held to-day at Lake Chapala, where more specifically it is believed that the nagual is a person transformed in part into an animal who enters a house with a basket to pilfer corn, beans or whatever is available. Fig. 2 expresses the tradition, representing a basket carried on the back of a four-legged, human or partly human faced creature. The Aztecs and the Quiché believed that shamans had the power to transform into animals; the early Spaniards also believed that witches could effect this transformation. The present-day Chapala belief[8] may be a fusion of Indian and Spanish beliefs.

[6] Compare the Quiché of Guatemala. Oliver LaFarge II and Douglas Byers, "The Year Bearer's People," 133–135. Middle American Research Series, Pub. 3. Tulane University, 1931; Mitla, 225–227.

[7] Starr, "Southern Mexico," VIII, 122.

[8] Compare the story of a woman who turns coyote to steal a lamb recorded in Nahuatl from Milpa Alta, D. F., by Dr. Boas (*Journal of American Folk-Lore*, 37: 360– 362, 1924).

Circular, shallow baskets are in use to-day, but they are not scalloped like the brims in Fig. 2 (left) and Fig. 3. Sometimes these modern baskets are left unfinished, *i.e.*, without a binding around the brim and the splints give the baskets a pointed appearance. Possibly these points are represented in the clay models, of which there are a large number of modern copies in Chapala.

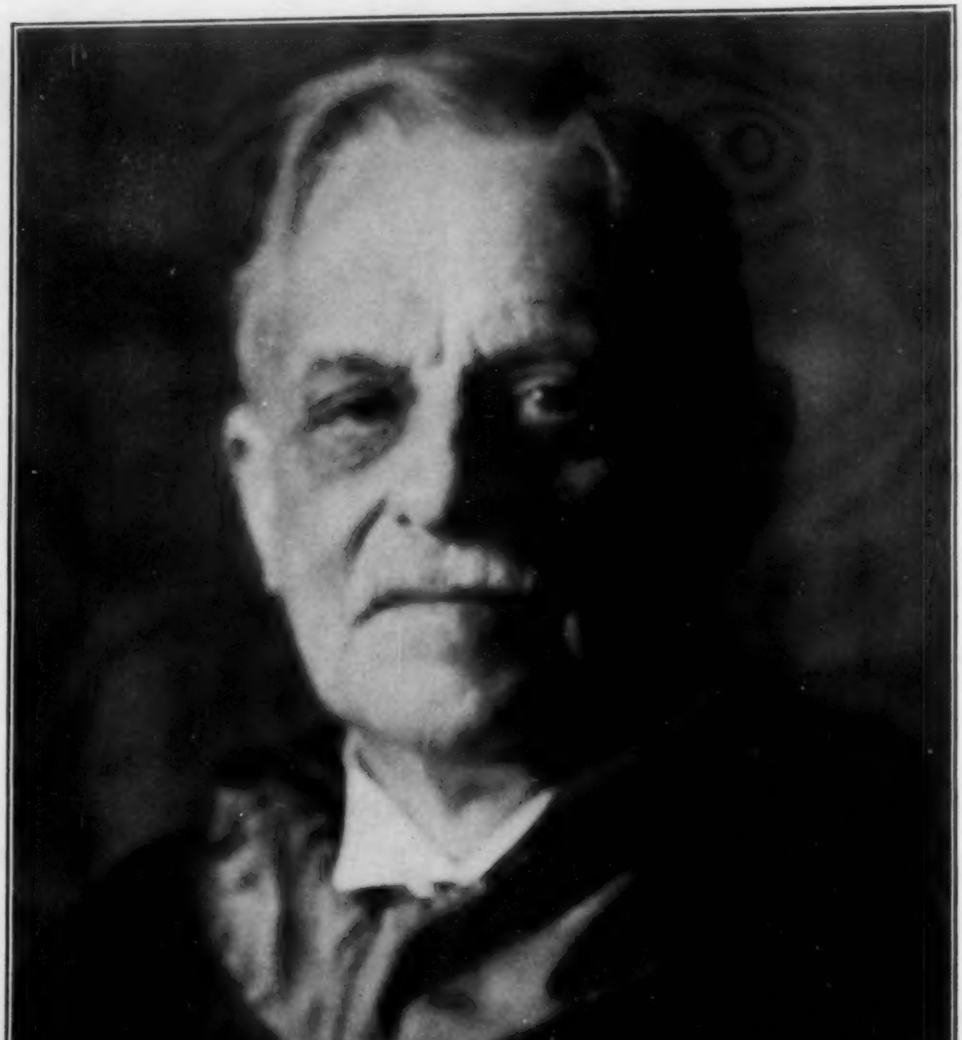
The animal figurine supporting a bowl which has a wide-spread distribution in Mexico has been found as near Chapala as Colima. A similar type of figurine may have been the model for the modern potter (compare Fig. 2 (right)), who merely emphasized human features in the animal head.

Although in this general region ancient pottery is distinguished by its representation of incidents of daily life, in Fig. 4 the modern potter has probably presented an entirely original design, that of the harvester on his knees, singing an *alabanza* or praise song, before he puts the crop into his basket. It is customary for the harvesters to make a circle around the pile of corn ears and to sing the song they call *álalavado*, the same song that is sung at midnight at the wake for the dead. It begins:

Cristo en cruz cruci—
Ficado
Que por me
Está este suerte.

"It is a long, sad song"; two persons sing, the others present joining in a refrain.

The modern potter of Chapala, the faker, whoever he is, is a clever craftsman. Unfortunately, it was impossible to meet him; he sells his wares through agents, as anonymity is essential to his market.



ELIHU THOMSON

THE PROGRESS OF SCIENCE

ELIHU THOMSON

Elihu Thomson, internationally noted inventor, engineer, researcher and teacher, was born at Manchester, England, on March 29, 1853. His parents were Daniel and Mary A. (Rhodes) Thomson. His father, a skilled mechanical engineer, was of Scotch descent, and his mother was English, of French Huguenot descent. In 1858 the family removed to America, settling in Philadelphia, Pa., when Elihu was five years old. In the public schools of Philadelphia Elihu as a child manifested inherited aptitude for mechanics and science, graduating from grammar school at the age of eleven years, sufficiently advanced in his studies to enter high school. But, as the entrance age for that school was thirteen, and the school officers considered Elihu unduly precocious, they advised setting his studies aside for two years. However, the boy was so unhappy without books that his mother provided him with elementary scientific literature and he began scientific experimenting and invention that continued unbroken throughout his life.

Young Thomson entered the Central High School of Philadelphia, at thirteen, where Dr. Edwin J. Houston, who was professor of natural philosophy, became greatly interested in his outstanding pupil; this attachment continued for life, the two men being subsequently in engineering partnership. When Thomson graduated from the high school in 1870, he continued at the school as instructor, and in 1875 became professor of chemistry and mechanics. During this period he lectured on electricity at the Franklin Institute in Philadelphia. In 1875 he built his first model dynamo, following this by other dynamo machines for arc lights in series, one of which was exhibited in 1877 at the Franklin Institute.

In conjunction with Professor Houston he invented a machine for the continuous centrifugal separation of substances of different densities, which, being particularly applicable to the separation of cream from milk, has come into extensive use in creameries. This was one of the first inventions connected with the name of Thomson to receive a U. S. patent, which patents during his life numbered over 700. In the winter of 1877–78 he served with Professor Houston in a committee of the Franklin Institute on dynamo-electric machines, and tests reported by them established a milestone in the art of dynamo-electric testing in this country. The following year Thomson and Houston developed a complete arc lighting system embodying many unique and ingenious features.

In 1882 the Thomson-Houston Electric Company was founded, with Professor Thomson as chief engineer and inventor. He then put into practical operation a number of electrical inventions that had been developed during his teaching period in Philadelphia. In 1883 the factories of the Thomson-Houston Company were moved to Lynn, Mass., where was initiated a period of phenomenal development in electrical engineering, extending from arc lighting to incandescent lighting, motors, transformers, distribution and electric railways.

Outstanding among the Thomson inventions was electric welding by the resistance method (patented in 1886). This has become more and more extensively applied in metal manufacturing industries. An invention of primary importance in electrical distribution was the Thomson integrating watt-hour meter, first exhibited in 1890 and applicable both to direct- and alternating-current circuits. It received half of the first prize in the Paris Electric Meter Competition of 1890. As is well known, it consists of a little electric motor, taking its small driving power from the electric circuit and recording upon a

dial in kilowatt hours the amount of energy delivered. Others had attempted to produce such a motor meter, but without success until Thomson employed a commutator of very small diameter with bars of pure silver and with silver brushes resting thereon.

Another invention of great practical importance was his magnetic blow-out for extinguishing arcs at switches and lightning protectors, by the mechanical force of a magnetic field in the immediate neighborhood of the arc. He contributed to the design and construction of internal combustion engines and improved the construction of turbo-ship propulsion and of electric railways.

After 1892, when the Thomson-Houston Company was merged with the Edison General Electric Company and others into the General Electric Company, Professor Thomson was associated with this great company as inventor, and consultant in engineering matters, patent litigation and general questions of policy. He was founder and director of the Thomson Research Laboratories.

Professor Thomson was recognized as one of those who have contributed most to the development of electrical science in the past fifty years. He was awarded the following medals: John Scott Medal of the City of Philadelphia; Franklin Medal of the Franklin Institute; Elliott Cresson Medal of the Franklin Institute; Rumford Medal of the American Academy of Arts and Sciences; John Fritz Medal of the American Engineering Societies; the first Edison Medal of the American Institute of Electrical Engineers; Hughes Medal of the Royal Society of Great Britain; Kelvin Medal of the British Engineering Societies; Faraday Medal of the Institution of Electrical Engineers, London; Grashof Medal of the Verein Deutscher Ingenieure. In addition he received the Grand Prix at the Paris Expositions of 1889 and 1900; the Chevalier and Officier crosses of the French Legion of Honor. His honorary degrees were bestowed as follows: A.M., Yale University, 1890; Ph.D., Tufts College, 1894; D.Sc., Harvard University, 1909; LL.D., University of Pennsylvania, 1924; D.Sc., University of Manchester (England), 1924.

Professor Thomson was a fellow of the American Association for the Advancement of Science, the American Institute of Electrical Engineers, of which he was president in 1889–90, the American Chemical Society, the American Philosophical Society, the American Academy of Arts and Sciences and the National Academy of Sciences. He was a member of the Institution of Civil Engineers of Great Britain, an honorary member of the Franklin Institute and of the Institution of Electrical Engineers of Great Britain. For many years he was a member of the corporation of the Massachusetts Institute of Technology, of which he was acting president in 1921–24. He was one of the six official U. S. delegates to the chamber of delegates of the Electrical Congress in Chicago in 1893; president of the International Electrical Congress in St. Louis in 1904, and succeeded Lord Kelvin as president of the International Electrotechnical Commission in 1908, serving for three years.

Personally he had the simplicity of manner which often marks the man of high attainments. He was an excellent speaker, and his lectures were remarkable for their directness and lucidity. He was married on May 1, 1884, to Mary L., daughter of Charles Peck, of New Britain, Conn., by whom he had four sons, three of whom survive him. Mrs. Thomson died in 1916. He was married on January 4, 1923, to Clarissa, daughter of Theodore F. Hovey, of Boston, Mass.

His death occurred on March 13, 1937, bringing to a close a long and remarkable career which greatly advanced the application of science to the world in which we live. Elihu Thomson will long be remembered as a great leader in American electrical engineering.

ARTHUR E. KENNELLY

SYMPOSIUM ON THE LIFE AND WORK OF RENÉ DESCARTES: CELEBRATING THE TERCENTENARY OF THE PUBLICATION OF HIS "LA GEOMETRIE"

THE publication in 1637 of Descartes' "La Géométrie," founding what is now known as analytic geometry, was one of the greatest events in the history of science and mathematics. For that single work did more than any other to emancipate the mathematical spirit from the 2000-years dominion of Euclid and thereby made possible the subsequent great mathematical developments that now constitute what is perhaps the chief intellectual glory of the modern world.

It was to signalize fittingly the immense importance of that seventeenth century deed of emancipation that *Scripta Mathematica* arranged the symposium on the achievements of the great emancipator, René Descartes (1596–1650), which was held on March 18 in the Horace Mann Auditorium of Teachers College, Columbia University. The meeting, attended by about 600 specially invited guests, was honored by the presence of a representative of the French Embassy in Washington.

Descartes' astounding versatility en-

DISCOURS

DE LA METHODE

Pour bien conduire ſa raiſon,& chercher

la verité dans les ſciences.

PLUS

LA DIOPTRIQVE.

LES METEORES.

ET

LA GEOMETRIE.

Qui ſont des eſſais de cete METHODE.

A LEYDE

De l'Imprimerie de IAN MAIRE.

CIↃ IↃ C XXXVII.

Auec Priuilege.

FACSIMILE OF THE "DISCOURS DE LA METHODE" PUBLISHED IN 1637

abled and led him to do memorable research in a wide variety of fields. Hence the desirability of providing a symposium of speakers, each specially qualified to deal with one or another of the various fields.

The speakers and their themes were as follows: "The Mathematical Contemporaries of Descartes," by Professor David Eugene Smith; "Descartes as Mathematician," by Professor Edward Kasner; "Method and Vision in Descartes' Philosophy," by Professor William Pepperell Montague; "Descartes as Scientist," by Professor Frederick Barry; and "Descartes as Physiologist," by Professor Horatio B. Williams.

In the near future *Scripta Mathematica* will publish the several addresses in full. Here it is possible to do no more than to indicate briefly one or two of the cardinal ideas in each of them.

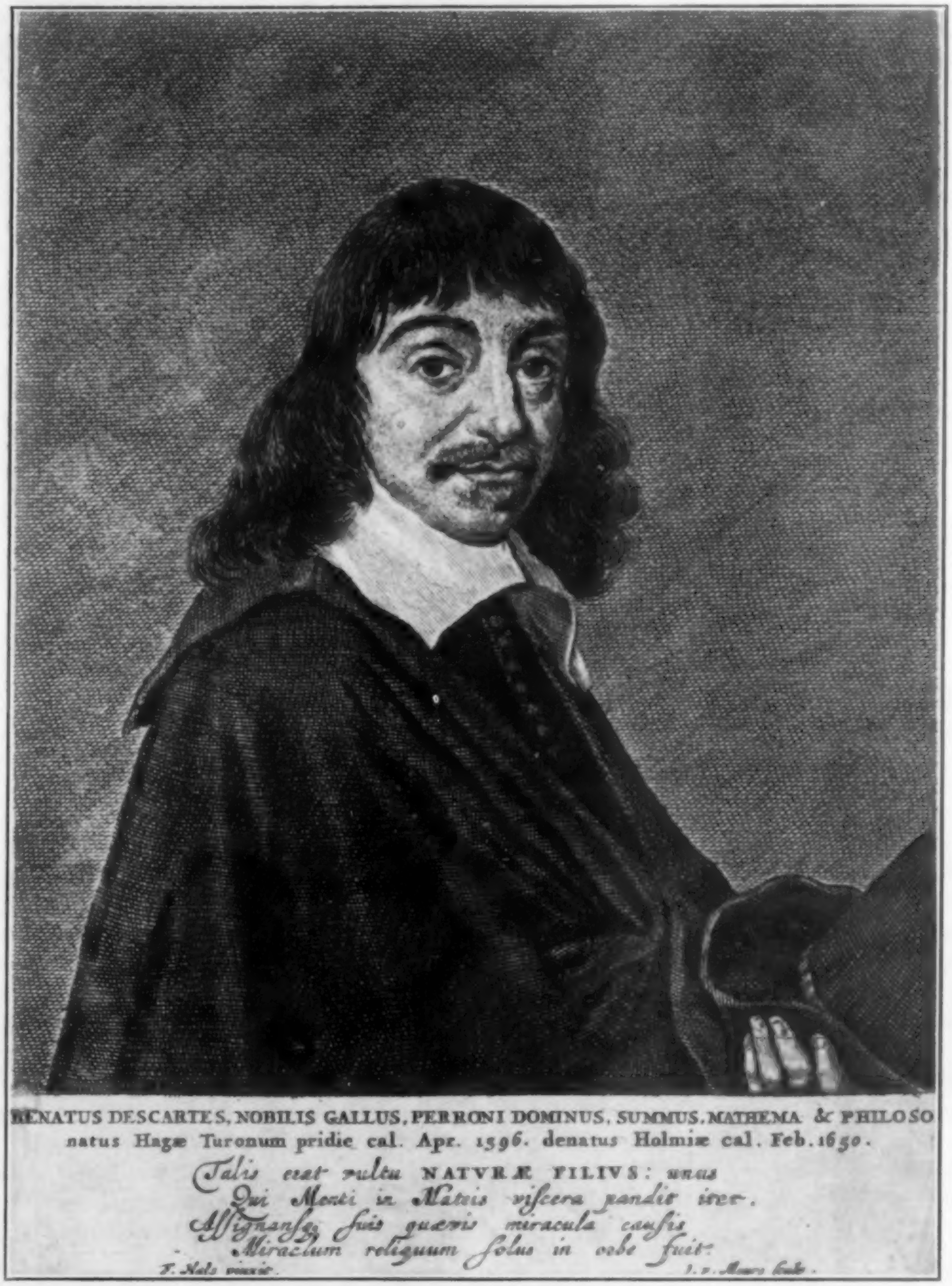
The writer of this note acted as chairman of the meeting. In his introductory remarks he endeavored to give a sense of the social atmosphere or mental climate in which Descartes was bred, lived his life and did his work. That the seventeenth century did probably more than any other both to honor and to dishonor the human spirit was shown by citation of the main characteristic facts of the time: on the one hand, such glorious facts as the prodigious fertility of the century in famous men and great contributions to literature, art, philosophy, medicine, physical science and mathematics; on the other hand, such inglorious facts as the prevalence of superstition, the absence of freedom of thought and speech, the more than continental mania of the Witch Hunt, and the still ghastlier horrors of the Inquisition.

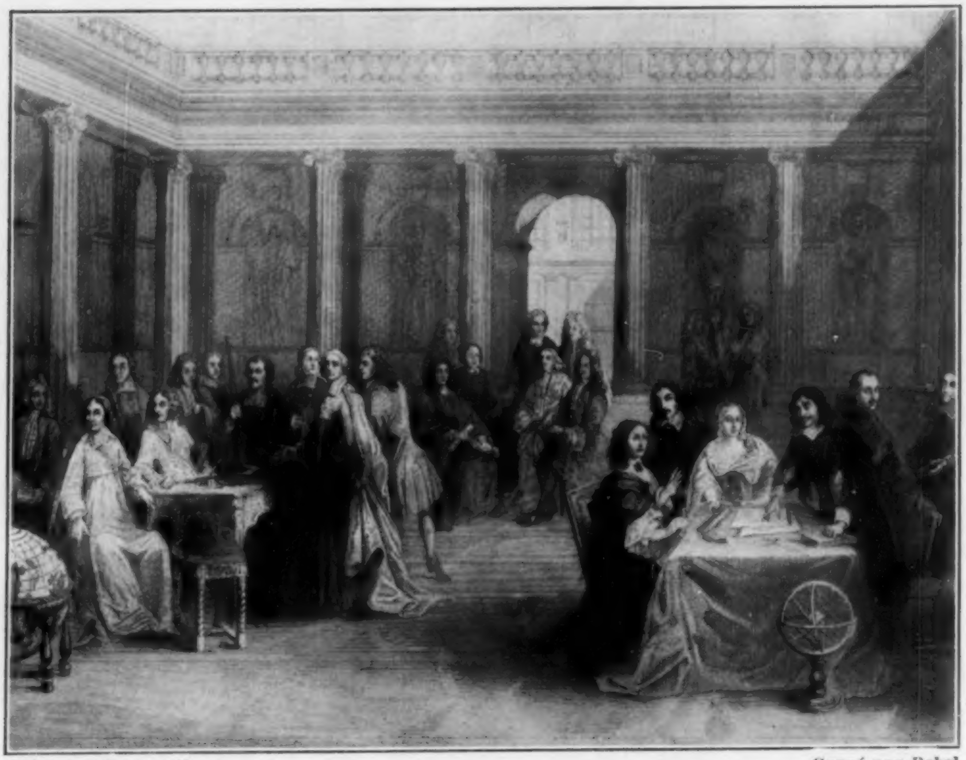
Among Descartes' mathematical contemporaries there were, said Professor Smith, three men who towered above the rest in creative power: (1) Pierre de Fermat, "the greatest genius in the theory of numbers up to his time and possibly of all times"; (2) the engineer Gérard Desargues, "the greatest geometer whom Descartes could have known, the most original of seventeenth century contributors to pure geometry," in fact, the founder of modern projective geometry; and (3) Blaise Pascal, "an infant prodigy who played with geometry as other children with toys, and at the age of sixteen published a famous essay on conics."

Professor Kasner pointed out that Descartes, "the founder of what is now called analytical geometry, never wrote a separate book on mathematics"; that his "La Géométrie," which, said Kasner, "will be eternal," was published, in the interest of philosophy, as only a relatively small part of the author's immense "Discourse on Method"; that "his book on geometry was not merely about geometry," but that in addition to the study of "curves—a very fashionable thing in the seventeenth century—it really contains a lot of algebra, equation theory, and the beginning of the calculus as well."

Descartes' aim, said Professor Montague, was to construct a cosmology having the charm of philosophy and the logical rigor of mathematics. The task's demands were two: (1) a set of axioms, or indubitable truths, to serve as principles; and (2) the deduction from these, in Euclidean fashion, of a true theory of the world. The Cartesian principles were either dubitable or trivial, and their alleged implicates sadly failed to follow logically. But, though Descartes' proofs were poor, his vision was great: a striking confirmation of Professor Montague's thesis that "philosophy is great, but its greatness is a greatness in vision."

"It is hardly possible," explained Professor Barry, "to distinguish Descartes the philosopher from Descartes the scientist." "The cosmology outlined in his 'Le Monde,' subsequently elaborated in


RENATUS DESCARTES, NOBILIS GALLUS, PERRONI DOMINUS, SUMMUS, MATHEMA & PHILOSO
natus Hagæ Turonum pridie cal. Apr. 1596. denatus Holmiæ cal. Feb. 1650.
Talis erat vultu NATVRÆ FILIVS: unus
Qui Menti in Matris viscera pandit iter.
Assignansq; suis quævis miracula causis
Miraclum reliquum solus in orbe fuit.



Peint par Dumesnil *Gravé par Rebel*

QUEEN CHRISTINE OF SWEDEN LISTENING TO A GEOMETRICAL DEMONSTRATION BY DESCARTES

his 'Principles of Philosophy,' served to coordinate all that was then known of the essential nature of things." It had, however, one fatal defect as a logically developed system—the concept of *mass* was absent—and had consequently to be rejected as erroneous. "Descartes' service to theoretical science is undeniable, but the results of his reasoning, owing to defective premises, were superseded by the work of such successors as Huygens and Newton."

"It has been denied," said Professor Williams, "even by Sir Michael Foster, that Descartes was a physiologist at all, it being alleged that Descartes merely wrote about the subject in connection with his philosophical speculations." But Dr. Williams, supported by the authority of Thomas H. Huxley, asserted that Descartes was "entitled to the rank of a great and original physiologist, an unwearied dissector and observer." In support of that judgment Dr. Williams quoted from Descartes a series of propositions "constituting the foundation and essence of the modern physiology of the nervous system."

The latest and best account of Descartes' life and great mathematical creation is found in a chapter of Bell's recently published "Men of Mathematics." In connection with the tercentenary celebration the publishers generously gave *Scripta Mathematica* reprints of Bell's account for free distribution. At the meeting it was announced that such a reprint together with a large portrait of Descartes reproduced from Smith's "Portraits of Eminent Mathematicians" may be obtained free by writing *Scripta Mathematica,* enclosing six cents for postage.

CASSIUS JACKSON KEYSER

DEAN FRANK CLIFFORD WHITMORE, HONORED BY THE AMERICAN CHEMICAL SOCIETY

Dr. Frank C. Whitmore, dean of the School of Chemistry and Physics of the Pennsylvania State College, has been elected president of the American Chemical Society for the year 1938. On March 5, he was presented with the William H. Nichols Gold Medal by the New York Section of the American Chemical Society in recognition of his researches in molecular rearrangements and the polymerization of olefins.

The Nichols Medal was established in 1902 by the late William H. Nichols to "stimulate original research in chemistry." In the words of the founder, this medal is to be given not solely because of advanced work of a constructive character, but particularly because such work has been made available to all chemists through publication. Among the more recent recipients are James Bryant Conant, president of Harvard University; Henry C. Sherman, Columbia University; Julius A. Nieuwland, University of Notre Dame; and William Mansfield Clark, Johns Hopkins University.

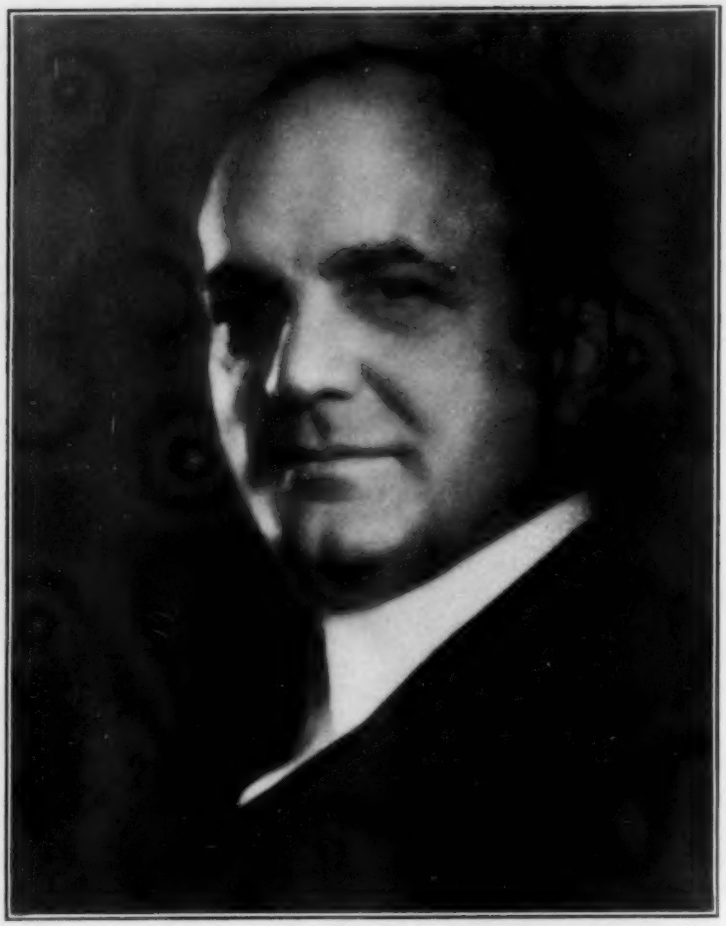
Before the presentation of the medal, Dr. Walter S. Landis, chairman of the Medal Jury of Award, announced that in order to insure perpetuation of the Nichols Medal, a gift of securities had been made to the New York Section of the American Chemical Society by C. W. Nichols, chairman of the board of the Nichols Engineering and Research Corporation and son of William H. Nichols. This generous and timely gift is in the form of securities of the Allied Chemical and Dye Corporation, perpetuating as successor the great industry of which Dr. William H. Nichols was so integral a part.

Dr. Whitmore was born at North Attleboro, Mass., on October 1, 1887. He spent his boyhood in New Jersey and Pennsylvania, and was graduated from the high school at Atlantic City. He was a member of the class of 1911 at Harvard University and received his master's degree there in 1912 and his Ph.D. in organic chemistry in 1914. He was instructor at Williams College during 1916–1917, and at Rice Institute during 1917–1918. In the latter year he was appointed assistant professor of chemistry at the University of Minnesota, and two years later became professor of organic chemistry at Northwestern University. After serving some years as head of the department, he went to the Pennsylvania State College in 1929.

Dr. Whitmore was chairman of Section C of the American Association for the Advancement of Science in 1932, chairman of the Division of Chemistry and Chemical Technology of the National Research Council 1927–1928, has been a director of the American Chemical Society since 1928, and was for eight years secretary and chairman of the Division of Organic Chemistry. In 1931 he was a member of the Council of the International Union of Pure and Applied Chemistry.

He is the author of 103 published research papers, of "Organic Compounds of Mercury" in the series of American Chemical Society Monographs, and his "Advanced Organic Chemistry" has just been published.

Dr. Whitmore's researches were begun under the direction of Professor Charles Loring Jackson and were first concerned with the anomalous reactions of sodium malonic ester. Throughout the years of his teaching at Minnesota and at Northwestern his attention was centered on the organic compounds of mercury. In the last ten years he has made a searching study of aliphatic compounds, including the dehydration of saturated alcohols, the determination of olefins, polymerization reactions and intramolecular rearrangements. His explanation of these rearrangements on an electronic rather



DEAN FRANK CLIFFORD WHITMORE

than an ionic basis has reduced to consistent order a very large number of formerly anomalous reactions.

Dr. Whitmore was one of the first to prepare an organic deuterium compound, neopentyl deuteride. Within the last two years his laboratory has worked with the sterols and sex hormones. His colleague, Professor R. E. Marker, has recently completed the synthesis of the female hormone, oestrone or theelin.

Dean Whitmore's election to the presidency of the American Chemical Society is a tribute not only to his scholarship and to his successful administrative record, but also to the simple, forthright charm that has won him friends in all parts of the country. His vigor, his inherent gaiety and his infectious enthusiasm have inspired work and devotion not only in thousands of students but in all parts of the chemical profession. To him any form of work is fun, and any form of research is grand fun—not the fun of conflict or competition, but the satisfying joy of discovery and creation.

GERALD WENDT

THE FIRST INTERNATIONAL CONFERENCE ON FEVER THERAPY

THE First International Conference on Fever Therapy was held in New York City from March 29 to 31, 1937. For more than a year plans had been formulating under the joint auspices of medical investigators from many countries interested in this new development in physical therapy and eager for the opportunity of exchanging experiences and comparing methods and results.

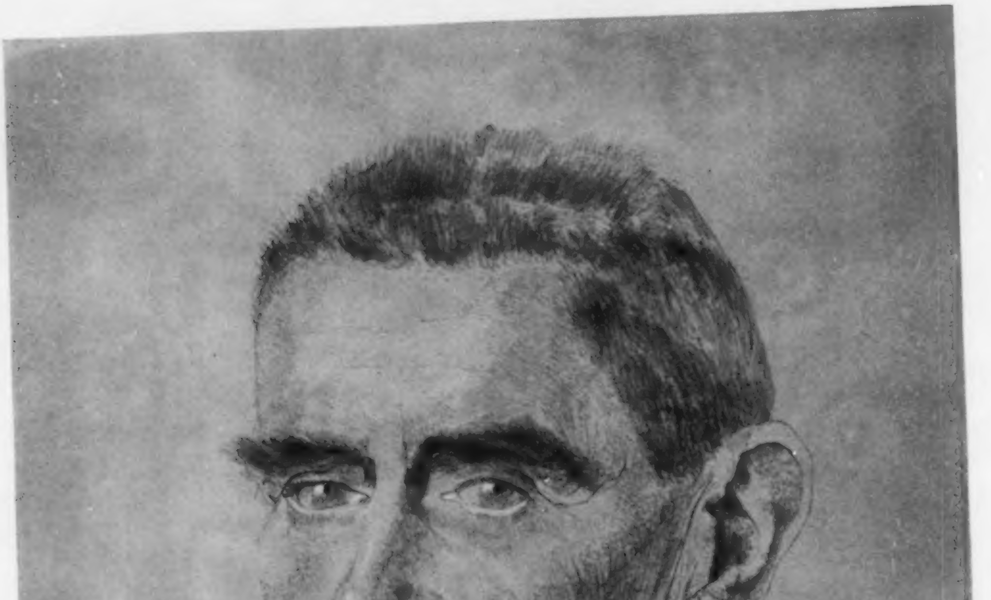
The present research interest and clinical activity in the field of hyperpyrexia date from the remarkably keen observations by Professor Julius von Wagner-Jauregg in Vienna, of remissions which not infrequently followed intercurrent infections in patients with general paresis. His analysis of this phenomenon led to the deduction that artificially induced, controllable fever might be a useful therapeutic agent, rather than a manifestation of disease only to be avoided and combatted. After trials with old tuberculin, vaccines, etc., von Jauregg finally inoculated patients with the plasmodium of malaria, controlling the paroxysms of chills and fever with quinine, as and when necessary. Such spectacular clinical results followed as to bring to him the Nobel Prize Award in medicine in 1927. Since that time this general therapeutic theory has been expanded and extended to a variety of pathologic states, and the fundamental mechanisms affected by fever and in turn potentially instrumental in combatting disease, have been subjected to careful scrutiny and experimental analysis.

It was altogether fitting, therefore, that Professor von Jauregg should have been made honorary chairman of this first international gathering of medical scientists to take inventory of the present status of fever therapy in the world today. The active chairman of the conference was Baron Henri de Rothschild, of Paris, its secretary Dr. William Bierman, of New York City. Official delegates representing their respective ministers of health were sent by Australia, Austria, Belgium, Canada, Chile, Colombia, Denmark, Dominican Republic, Ecuador, England, France, Greece, Mexico, Nicaragua, Salvador and Yugoslavia; representatives were also present from Germany, Brazil, Holland, Hungary, Italy, North Africa, Norway, Poland, Portugal, Roumania, Spain, Sweden, Switzerland, Turkey and Russia; the United States Army, the Navy and the Public Health Service were each represented by official delegates, as were the New York City Departments of Health and of Hospitals.

The first day's sessions were held at the College of Physicians and Surgeons, Columbia University. Professor Pierre Abrami, president of the French committee and professor of medical pathology, University of Paris, replied to the address of welcome extended by Dr. Allen O. Whipple. Messages were read from Professor Julius von Wagner-Jauregg and Professor d'Arsonval.

The scientific papers on the first day dealt with the relative merits of the various methods of inducing fever and the more fundamental underlying physiological, chemical and pathological phenomena which accompany or result from pyretotherapy.

At the very beginning in Professor von Jauregg's message and repeatedly reemphasized throughout the three days of addresses was the necessity for the utilization of every other known specific and non-specific measure *in combination with* fever therapy, if the optimum clinical results are to be obtained in the treatment of the diseases under discussion. Pyretotherapy is not a specific therapeutic procedure even in those diseases where the known etiologic agent is sufficiently thermolabile to be inhibited or killed at human fever levels. Von Jauregg wrote: "For reasons not far to seek, it was thought that the therapeutic process might be due to the high tempera-



PROFESSOR JULIUS VON WAGNER-JAUREGG

ture level observed in malarial treatment. I was quoted as holding this opinion myself, but this is far from correct. As early as 1887 and 1895 I voiced the opinion stating that the high temperature level is nothing but an index for the intensity of a therapeutic process running its course in the organism. Since then I have stressed this view again and again." Professor Abrami summarized the present methods in fever therapy as comprising two completely distinct approaches: the one, intrinsic, through the body's own reaction to injected foreign materials of various types, as exemplified in the "shock" reactions to peptone, sulphur, vaccines, malaria, etc.—reactions controllable neither as to frequency, intensity or duration, as pointed out by Professor Richet, and, therefore, susceptible of much harm and even death in weakened individuals; the other, extrinsic, in which the body passively responds to physical agents in the environment—electrotherapy, radiotherm or hypertherm—and with which exact dosage is under the immediate and continuous control of the physician. Professor Abrami stated his belief that the uniformly beneficial results reported, following the use of each of these methods, represent the sum of very complex biological reactions, especially important modifications which take place in the functional state of the neurovegetative system. These biological reactions, which are almost always associated with a febrile attack, can sometimes occur in the absence of hyperthermia, with the production of the anticipated therapeutic results; conversely, fever may not be followed invariably by clinical improvement. It was the consensus of opinion among those attending the conference that there is no "ideal" single method of fever induction at the present time and probably never will be, because of the individuality of the problem as it presents itself in different diseased states in different patients. In the last analysis personal medical judgment must be exercised, as in every medical problem.

Dr. Hardy, of the Russell Sage Institute, discussed interference with heat loss in the human body as being the chief mechanism through which fever temperatures are attained. The changes in blood volume, acid-base equilibria and especially the chloride balance in artificial fever were presented by Dr. Gibson and his associates from the Harvard Medical School, and by Dr. Stafford Warren, of the Rochester School of Medicine.

The cytologic reactions to fever, induced by the various means already cited, in partial explanation of how fever effects its results, were discussed by Dr. Doan, of Ohio State University's College of Medicine. The lymphoid elements are destroyed and their regeneration inhibited during fever, whereas the bone marrow reacts promptly with new and increased numbers of granulocytes. The phagocytic elements are greatly stimulated irrespective of the method used for inciting the fever reaction. Dr. Hartman, pathologist at the Henry Ford Hospital, Detroit, analyzed the post-mortem findings in fatal instances of hyperpyrexia.

From the clinical view-point the outstanding therapeutic success to date in the application of pyretotherapy to disease has been in gonorrheal infections. A half day's symposium was devoted to the presentation of the scientific and clinical data in this area. When systemic fever therapy is combined with additional local heat, as advocated by Bierman, of New York, and Krusen, of the Mayo Clinic, for periods of time which may be accurately determined for each patient through *in vitro* thermal death time studies of the gonococcus as advocated by Carpenter and his associates at Rochester, N. Y., a complete cure may be accomplished in more than 90 per cent. of the cases. Gonorrheal arthritis, especially, and endocarditis have been successfully treated by fever therapy.

Because of the biologic similarity of the meningococcus to the gonococcus, Dr. Mary Moench, of the Cornell University Medical School, reported *in vitro* studies of fifteen strains. Five were either destroyed or greatly inhibited at 41° C. after five hours, seven showed moderate reduction in growth, and three were not appreciably affected after seven hours. In selected cases, especially septicemias, in which specific serum therapy has failed or can not be used, fever therapy is felt by Dr. Moench to be worthy of trial as an adjunct to other measures.

Another half day was devoted to the experimental and clinical studies in syphilis with fever therapy. The evidence seems to justify the conclusion that artificial fever fortifies and intensifies the curative action of chemotherapeutic agents, both in early visceral and in late neuro-syphilis. Simpson, Neymann and others reported a higher proportion of remissions with a lower mortality rate, using physically induced fever, than have been reported statistically following malaria. The one exception is the report of Dr. Maurice Ducoste, medical chief of the Psychiatric Hospital at Villejuif, France, who introduces the malarial blood intracerebrally. Of 435 patients with general paresis treated in the past ten years 353 or 81 per cent. are reported cured; there were 25 deaths (6 per cent.). Before the introduction of this form of malaria treatment 73 per cent. of the patients of this type died during the first six months and 88 per cent. during the first year in this institution.

A variety of other conditions have been subjected to fever therapy in an attempt to supplement a limited or unsatisfactory therapeutic rationale. Among these are acute rheumatic fever, chorea and acute and chronic infectious arthritis. Simmons and Dunn, from the University of Nebraska, Osborne, Blatt and Neymann, of Chicago, and Barnacle, Ewalt and Ebaugh, of Denver, confirmed the encouraging results reported by Dr. Lucy Porter Sutton and Dr. Katherine Dodge, of New York University, in chorea and rheumatic carditis. Dr. Stecher, from Western Reserve, reported excellent results in acute non-specific arthritis. More time must elapse before a full and complete evaluation can be made of the final place fever will occupy in the treatment of these and other miscellaneous conditions.

It must be emphasized that much remains to be learned with respect to the indications and the contraindications for artificial fever therapy as applied to human disease. It is a therapeutic procedure which should be rigidly limited at the present time to hospital or institutional administration under trained medical and nursing supervision, where every means is available for meeting the emergencies which occasionally arise. Much encouragement may be derived, however, from the cordial and frank exchange of ideas and experiences which the conference just concluded provided, and in the knowledge that medical investigators the world over are pooling their resources to bring to diseased individuals safely and promptly these new therapeutic measures.

The Government of France through the Ambassador at Washington and the Consul-General in New York officially recognized the contributions of American investigators to the field of fever therapy by conferring the cross of the Legion of Honor on Messrs. Kettering and Whitney and Drs. Bierman and Simpson during the conference. The modern spirit of collaboration of engineer and physician, of physicist and biologist, in the conquest of disease has been unusually clearly and splendidly shown throughout the writing of the American chapter in the development of physical therapy.

CHARLES A. DOAN, M.D.,
Secretary, Section on Physiology and Pathology